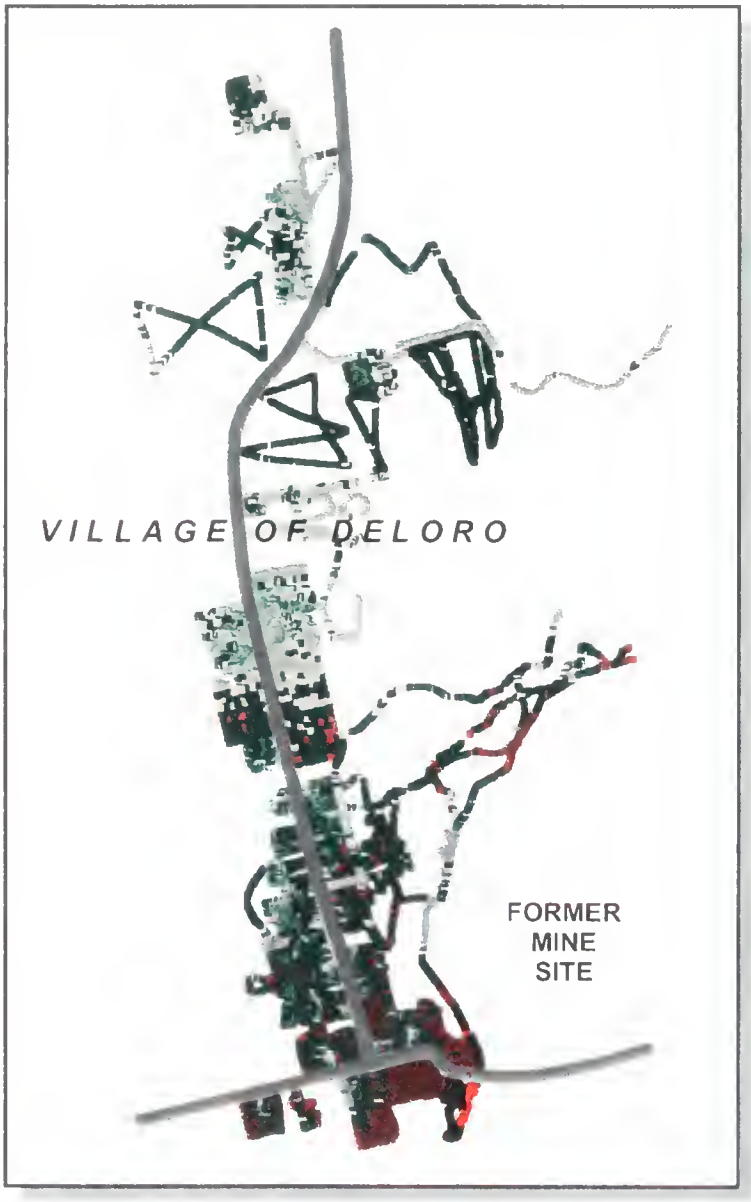
Radiological Health Risk Assessment for the Village of Deloro

July 1999



Prepared for:

Ontario Ministry of the Environment

Prepared by:

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SUMMARY

Background

The Village of Deloro Ontario, located on the Moira River approximately 8 km east of Marmora, is the location of a former gold mine and smelter. The mining of gold in the vicinity ceased in the early 1900s but the smelter continued to operate into the 1950s processing ores from elsewhere in Ontario and from other countries. Some of the ores processed at the site contained high amounts of arsenic and other metals, while other ores contained elevated quantities of natural radioactivity, specifically the uranium decay series radionuclides.

The site has been the focus of several studies and remediation efforts by the Ontario Government, including the operation of an arsenic treatment plant to control discharges of arsenic to the Moira River. The MOE initiated an extensive environmental monitoring program in the summer and fall of 1998 to assess the potential exposures of Deloro residents. This study reports on the assessment of potential radiological risks to residents of Deloro. A parallel study assesses the potential risks from arsenic and other metals.

Objectives

The main objective of this assessment was to estimate the potential radiological doses and consequent risks to people living in the Village of Deloro. In the context of this report, "risk" was taken to mean the lifetime risk of cancer resulting from a lifetime of exposure in Deloro. The potential doses and risks from natural background radiation were also estimated to provide a context for discussing the potential requirements for reducing radiation exposures in Deloro, if considered necessary.

Results

In considering the results of this analysis, it is important to remember that radioactivity and radiation are ubiquitous. Exposure to radiation and radioactivity is a part of our everyday life and is unavoidable. Thus, for exposure to radiation and radioactivity, comparison to natural background levels of radiation and radioactivity provides a useful context. The probabilistic risk assessment produced distributions of doses and risks for both Deloro-specific concentrations and for the range of natural background exposures estimated for geologically similar areas in Ontario.

Based on the results of this study, the radiological doses and lifetime risks predicted for current residents of the Village of Deloro are comparable to and within the range of doses and risks for Ontario residents from natural background radioactivity.

On an annual basis, the estimated annual radiation dose to an adult living in Deloro, including both natural background for the area and the incremental contribution attributable to the mine site, was estimated at about 1.2 millisieverts/year (mSv/y), as compared to 1.1 mSv/y estimated for typical background exposures. The corresponding maximum likely dose for the adult (maximum likely dose is taken as the 95th percentile) was about 2.9 mSv/y from natural background as compared to 2.7 mSv/y for a Deloro resident. The average dose to a one year old was estimated at about

1.5 mSv/y, as compared to 1.4 mSv/y estimated for natural background conditions. The corresponding maximum likely doses to a one year old were estimated at about 3.7 mSv/y from natural background conditions compared to about 3.3 mSv/y for a Deloro resident.

Estimates of lifetime risk from a lifetime of exposure were calculated for Deloro and natural background conditions. Since dose and risk are directly related, the estimated risks from radiation were similar for residents of Deloro and people exposed to natural background radiation. The mean value for lifetime risk from exposure to natural background was 6.2 per 1,000; this is slightly lower than the mean risk under typical Deloro conditions which was about 6.6 per 1,000 over a lifetime. The maximum likely lifetime radiological risk from natural background conditions was estimated to be about 1.6 per 100; this risk is slightly higher than the maximum likely risk, 1.5 per 100, estimated for Deloro conditions.

The risk to Deloro residents from periodic casual access to the former Deloro mine site was estimated to be less than about 5% of the mean risks estimated for the average Deloro resident.

The major contributor to lifetime risk was radon which accounted for about 70% of the average lifetime risk for Deloro conditions. Gamma radiation and water ingestion accounted for about 17% and 11% of the mean lifetime risk, respectively. The estimated risk from water ingestion is highly uncertain, and in all likelihood, an overestimate since the risk is driven by the laboratory reporting limits. (The water concentrations were below the reporting limits; however the concentrations were assumed to range up to the reporting limits for the risk assessment.) The drinking water pathway assumes the same uncertainty for all zones including natural background and, therefore, the doses from this pathway are identical for the Deloro resident and a person exposed to natural background conditions. Risk from inhalation of airborne dust and ingestion of soil, dust, and home garden produce accounted for about 1% of the total lifetime risk.

A sensitivity analysis indicated that the lifetime risk estimates were most sensitive to variability in the indoor radon concentrations. The variability in indoor radon concentrations explained more than 95% of the overall variability in the lifetime risk. Typically, the variation explained by each of the other input factors was less than 1%.

Estimates of the mean annual doses to adults from natural background and also from present conditions in Deloro are shown in the Table below. The Table also shows the upper 95th percentile estimate of the total annual doses. The ratio of the 95th percentile annual dose, which is an estimate of the maximum annual dose that anyone is likely to receive, to the mean annual dose average is between about 2 to 3.

Although the estimated doses and consequent risks for residents of the Village overall are comparable to the range of those from natural background, there is an indication that there is a gradient in dose and risk from gamma radiation, with dose and risk decreasing with increasing distance from the former Deloro mine site. The major contributor to the potential gradient is the relative elevation in gamma radiation levels close to the mine site that are attributable to radiation contamination on the mine site. It is possible that some gamma radiation may arise from contaminated materials located off-site. The distribution of natural mineralization may also be a factor in the observed gradient.

Location	Mean Total Dose (mSv/y)	Mean Gamma Radiation Dose (mSv/y)	Mean Radon Dose (mSv/y)	95th Percentile of Total Dose (mSv/y)
Background	1.1	0.16	0.81	2.9
Deloro Village	1.2	0.20	0.85	2.7
Zone 1 (furthest from the mine site)	1.6	0.18	1.3	3.8
Zone 2	0.97	0.18	0.67	2.1
Zone 3	1.0	0.20	0.72	2.2
Zone 4 (nearest to the mine site)	2.7	0.23	2.3	6.3

With respect to radon, elevated outdoor radon levels were observed near the site fence and therefore, for the area closest to the mine site, there is a possibility of some small elevation in the radon levels that could be attributed to site contamination. Radon doses are dominated by indoor levels and radon doses were highest in the nearest and furthest zones from the site. It must be emphasized that natural background levels of radon are highly variable and would naturally vary widely from home to home even in the absence of radioactive contamination.

Although residents of Deloro do not appear to be exposed to levels of radiation and radioactivity above those from the typical range of background, there is a suggestion that close to the mine site the radiation levels may be elevated relative to those further away from the mine site. Thus, consistent with the radiation protection principle that doses from radiation should be as kept as low as reasonably achievable, social and economic factors taken into account (ALARA), some consideration should be given to practical measures to reduce radiation risks.

Gamma radiation levels can be readily reduced through shielding and distance. Thus, contaminated materials at the perimeter of the site (and in off-site pockets) could be moved away from the perimeter which would reduce off-site gamma levels. In addition, gamma radiation levels are attenuated by covering with soil or other natural materials. For example, a 10 cm thick layer of compacted soil would reduce the gamma radiation levels by a factor of about 2 and a 20 cm cover would reduce gamma levels by a factor of about 4. Consolidation and cover of on-site radioactive materials would reduce gamma radiation exposures to Deloro residents.

With respect to radon, the outdoor radon levels appear to be elevated close to the mine site relative to the assumed levels of natural background. Radon is also attenuated by soil cover, although not nearly so effectively as it is for gamma radiation. For example, to reduce radon flux by a factor of about 2 would require about a 1 m thick soil cover. Further investigation would be required to evaluate with confidence whether the elevated outdoor radon levels near the site are in fact a reflection of normal variation or rather the result of radioactive contamination.

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1.0 INTRODUCTION

1.1 BACKGROUND

Deloro, Ontario, located on the Moira River approximately 8 km east of Marmora, is the location of a former gold mine and smelter that began in the 1860s and continued until 1961. Among other contaminants, the ore had a high arsenic content. The mining of gold in the vicinity ceased in the early 1900s but the smelter at the site was used to process ores from Northern Ontario mines and from other countries around the world. In addition, operations at the Deloro mine site in the 1930s to 1950s involved the reprocessing of uranium and radium (Ra-226) residues from the Eldorado refinery in Port Hope for the recovery of cobalt and other metals. The long history of the site has resulted in contamination of the site with arsenic and other metals, including radioactive tailings and slag.

The site has been the focus of several studies and remediation efforts by the Ontario Government, including the operation of an arsenic treatment plant to control discharges of arsenic to the Moira River. Residents of the Village of Deloro are potentially exposed to above-background levels of arsenic, other metals, and gamma radiation and radioactivity due to their proximity to the Deloro mine site. An analysis by the Ontario Ministry of the Environment (MOE) had indicated that the arsenic and other heavy metals, as well as the radioactive materials on the site, were potential health concerns to the people of Deloro. As a result, the MOE initiated an extensive environmental monitoring program in the summer and fall of 1998 to assess the potential exposures of Deloro residents, and to determine the potential risks to the residents.

The overall Deloro Village environmental health risk assessment is being managed and coordinated by CH2M Gore and Storrie Limited (CG&S) on behalf of the MOE and includes separate risk assessments of the residents of Deloro for potential exposure to the chemical and radiological contaminants. SENES Consultants Limited (SENES) was retained by the MOE through CG&S to undertake the health risk assessment for radionuclides, gamma radiation and radon. The radiological risk assessment is the subject of this report.

1.2 STUDY OBJECTIVES

The objectives of the present assessment were to:

- Quantitatively estimate radiological doses and potential risks to Deloro residents from exposures off the mine site using, where possible, data specific to Deloro and environs.

- Compare the estimates of radiological dose and risk attributable to the mine site to background levels at other locations and assess the incremental contributions to the risk from current site emissions (e.g. of airborne radon) and any historical deposition (e.g. the build up in soil).

- Conduct a probabilistic analysis to demonstrate the variability in the estimated risks due to the spatial variability in environmental concentrations and from the variability in exposure patterns of the residents of Deloro.

- Conduct sensitivity analyses to determine the main contributor to the estimated risks, the effect of uncertainty on the estimated risks and to identify any key data deficiencies.

- Discuss potential remediation approaches that could be taken to reduce radiological risks if considered necessary.

It should be noted that, in the context of this report, "risk" was taken to mean the lifetime risk of cancer resulting from a lifetime of exposure of the residents of Deloro to gamma radiation, radon and other radionuclides. This is discussed in more detail in Section 3.2.

While exposures and potential risks from exposures occurring in the Village of Deloro (i.e. off the mine site) were the focus of this study, the issue of exposures from periodic on-site access was also evaluated. A description of the study methodology and results of the assessment are provided in subsequent sections of this report.

Because the subject matter of this report (radiation and radioactivity) may be novel to some readers, a brief introduction to natural background radiation and some radiological terms is presented in Appendix A.

1.3 PROBLEM DEFINITION

In performing radiological risk assessments, the radiation doses via all potentially significant exposure pathways are estimated and summed to arrive at the total radiation dose to the receptors (people) under consideration. The resultant doses are then multiplied by appropriate risk factors to estimate the resultant risks. These tasks require: the characterization of the site under study so as to address the nature and extent of the contamination relative to potential exposure of receptors; the identification of the contaminants of concern; the identification of potential receptors who are most likely to receive the greatest exposures; and the identification of the potential exposure pathways by which the various receptors are exposed to the contaminants under study.

1.3.1 Study Area

As previously noted, the focus of this study was the assessment of potential radiological exposures and risks to residents of Deloro attributable to sources of radiation and radioactivity on the mine site. Deloro consists of approximately 140 people located in 65 residences, located mainly in a north-south direction along O'Brien Road, the major street in Deloro. In order to address the potential spatial variability of any above-background levels of radiation and radioactivity relative to the distance from the former Deloro mine site (located on the Moira River to the southeast of the Village), the study

area was divided into four zones, sequentially numbered Zone 1 (the most northerly zone in Deloro) to Zone 4 (located adjacent to the former mine site). The zones are shown in Figures 1.1a and 1.1b. The demarcation of the zones was reached in discussion with the MOE and the study team. In brief, Zone 1 refers to the media and site characterization data for residences north of 75 O'Brien Road; Zone 2 refers to residences between 43 and 75 O'Brien Road; and Zone 3 consists of the remaining residences with the exception of those located on Private Road, or Zone 4 closest to the former mine site.

Except for the gamma radiation and radon survey data taken from SENES (1999), summaries of the site characterization data were provided to the study team by CG&S. All dose and risk estimates shown in this report were subdivided according to these zones. In this manner, any potential variability in the estimated risks with distance from the former mine site, the presumed source of any contamination in Deloro, could be identified. Dose and risk estimates based on the combined data for all Deloro were also calculated. Additionally as previously noted, direct exposures and risks resulting from periodic casual access to the former mine site for recreational purposes (e.g. hiking) were separately evaluated. The potential exposure duration used in the calculations for such site access was based on discussions with the MOE, CG&S and the study team.

1.3.2 Radionuclides Addressed in This Study

The sources of the above-background levels of radiation and radioactivity in Deloro were the uranium and radium (Ra-226) residues from the uranium refinery in Port Hope. These materials contain natural uranium and associated radionuclides in the U-238 decay series, including Ra-226 and the gas Rn-222 (radon) (Appendix A). Because the environmental concentrations of the short-lived radionuclides are determined by the presence of the long-lived radionuclides in the series, this study specifically addressed potential exposures to the longer-lived radionuclides in the U-238 series, namely, U-238, U-234, Th-230, Ra-226, Pb-210 and Po-210. Estimating exposures to these radionuclides, including the associated gamma radiation exposures, implicitly accounts for the exposures of the shorter-lived radionuclides. The special case of exposure to radon gas and its progeny, which can be released from radium-bearing materials and be dispersed throughout the atmosphere, was also evaluated. Radon progeny are typically the largest contributors to background radiation exposures,.

Potential exposures to the natural thorium (Th-232) decay series were not estimated. Historical measurements of 27 samples from borehole and test pits on the Deloro mine site show natural thorium levels ranging from < 0.5 to 19 ppm (with one sample at 37 ppm) (Golder 1988). Natural thorium levels in wastes inventoried at the site ranged from < 1.0 to 12 ppm (with one sample at 28 ppm) and averaged <4 ppm. These data indicate essentially background levels (e.g. U.S. NCRP 1987). Additionally, measurements of thorium in groundwater and surface water samples were almost all (43 of 45 samples) below the limit of detection (0.05 mg/L) (Golder 1988). Following up on the historical data, the most recent radiological characterization of materials on the mine site focussed on measurements of gamma radiation, uranium and Ra-226 levels (SCIMUS 1998). Based

on this information and discussions with the MOE, potential exposures to natural thorium were not considered relevant to this study, and were not addressed.

1.3.3 Exposure Pathways Evaluated

Exposure pathways analysis basically traces the pathways through which contaminants move from the source or sources of contamination through the environment to expose the receptors (people) of concern. Pathways by which the residents of Deloro could be exposed and which were evaluated in this study included:

- external (to the body) gamma radiation indoors and outdoors;
- inhalation of radon progeny indoors and outdoors;
- ingestion of home-grown garden produce;
- inhalation of airborne dust indoors and outdoors; and
- ingestion of dust/soil indoors and outdoors.

Following discussions with the study team, the ingestion of drinking water (groundwater) was also considered for completeness although there is no evidence to indicate that this pathway has been impacted by any radiological contamination.

As agreed to in discussions with the MOE, other potential exposure pathways such as swimming or eating fish from the Moira River, or dermal (through the skin) exposures to the radionuclides under study, were considered insignificant and were not evaluated in this study.

1.3.4 Receptors Analyzed

In undertaking radiological risk assessments, it is necessary to identify the "critical" group or groups, that is, those receptors most likely to receive highest exposures as a result of their lifestyle characteristics (e.g. where they live, what they eat, etc.) and who have the highest potential risks as a result of their relative sensitivities to radiation exposure. Because most of the parameter values required for the pathways analysis are age-dependent (e.g. breathing rate, radiation dose conversion factors), the analyses in this study were undertaken to cover the entire range of ages of residents in Deloro. Specific analyses were undertaken for the following age groups:

- 1 year old (from 1 y to 2 y)
- 5 year old (more than 2 y to 7 y)
- 10 year old (more than 7 y to 12 y)
- 15 year old (more than 12 y to 17 y)
- adult (more than 17 y).

These age groups were chosen because of the availability of age-dependent dose conversion factors for these specific ages from the International Commission on Radiological Protection (ICRP). The

ICRP (1996) considers that the age-specific dose conversion factors for each age group can be applied to the ranges of ages noted above.

The various age groups were all assumed to be exposed to the same pathways noted above. Based on the recommendation of the MOE, the exposure and consumption parameter values applicable to each age group used in this assessment were based primarily on a compendium of Canadian human exposure factors published by Richardson (1997). Richardson summarizes the available data on exposure parameters from Canadian and U.S. sources (those which were considered generally applicable to the Canadian population), and recommends parameter values and distributions as a function of age for use in risk assessments. The values selected are discussed later in this report.

The age-dependent parameter values and estimated doses and risks in this assessment were considered to apply to both males and females. While some parameter values do vary somewhat with sex (but generally by less than 10% to 20% based on Richardson (1997) and U.S. EPA (1997), especially for the younger age groups), the variation was considered small in the context of other sources of uncertainty in this assessment. Moreover, the radiological risk factors of the ICRP that were used in this study are averages over both sexes and are considered by the ICRP to be appropriate factors when undertaking risk calculations of the general population. The ICRP (1991) has stated that, although there are differences between the sexes, they are not so large as to necessitate the use of different risk coefficients.

1.4 Risk Estimation and Study Methodology

1.4.1 Risk Estimation

The estimation of radiological risks for the residents of Deloro was performed as follows. The concentrations in various environmental media were combined with the appropriate age-dependent exposure, intake and dose conversion factors to estimate radiation dose for each year of exposure. The calculations were carried out for each of the age groups and each of the exposure zones within Deloro as described above. In this way, both the age and spatial dependence of the estimated annual doses were calculated. This was done for the both media concentrations and exposure rates specific to Deloro and for typical background radioactivity and radiation levels.

To arrive at estimates of lifetime risks for a lifetime of exposure, the annual doses were first multiplied by the appropriate years of exposure for that age group and the corresponding age-dependent risk factors to arrive at an estimate of the lifetime risk associated with each age group. For example, the annual dose for the 5 y old was multiplied by 5 and the risk factor for a 5 y old to estimate the risk accumulated over that time. (The durations of exposure used were 2 y, 5 y, 5 y, 5 y, and 53 y for the 1 year, 5 year, 10 year, 15 year and adult age groups, respectively. The 53 y duration for adults was based on the difference between 70 y, the assumed lifetime, and 17 y, the total exposure duration for the other age groups.) This was repeated for all age groups, and the risks accumulated for each age group were then summed to estimate the total lifetime risk from a potential lifetime of exposure in

Deloro. This was done first assuming exposures only within each of the four zones and then assuming exposures over all zones in Deloro. The lifetime risk from exposure to background radiation levels was similarly estimated for comparison to the risks estimated for Deloro residents.

It should be noted that this calculation is somewhat conservative because it assumes that all of the committed dose is actually delivered to the organs of interest. (Radionuclides continue to irradiate the body after exposures have ceased - see Section 3.2.1.) For external gamma radiation and radionuclides with relatively short half-lives, this is a correct assumption. For radionuclides with half-lives of several years, this is a conservative assumption that will overestimate the actual dose delivered. In reality, the exposed person is likely to die from natural causes before the full committed dose is received.

1.4.2 Deterministic and Probabilistic Analyses

Two methods are often used in carrying out exposure and risk assessments. The first involves the selection of single values, or point estimates, for each of the parameters used in the calculations to arrive at single estimates of risk for the receptors under consideration. In this "deterministic" technique, the parameter values are chosen from the possible range of values so as to (reasonably) maximize the estimated risks. Analyses performed with the deterministic (i.e. single value) techniques are often referred to as "worst-case" estimates. This approach is often considered useful in screening level risk assessments to determine the potential relative importance of various exposure pathways and contaminants, and to determine which pathways which might require more detailed analyses.

Doses and risks can also be estimated using "probabilistic" analysis to capture the effects of variability in location, environmental concentrations and other factors. In a probabilistic analysis, the input parameters needed to evaluate the dose and risk models are described not as single values but rather as distributions which are intended to reflect the natural variability and uncertainty within a particular category or parameter. The calculations are performed repeatedly, with new values randomly selected (using simple, random Monte Carlo sampling in this assessment) from each of the distributed input values for each calculation. The results of such an analysis are then probability distributions of dose or risk which can be used to calculate the normal statistical descriptors such as the arithmetic mean, median, and percentiles. The results can also be used in a sensitivity analysis to help identify those parameters which contribute most to the dose or risk or the most to the variability in the dose and risk. Additional uncertainty in the estimates of dose and risk arises from limitations on how well we understand an exposure pathway or parameters needed to evaluate the pathway. Both these issues, sensitivity and uncertainty, are discussed in this report.

For the purposes of this assessment, deterministic analyses were first performed using the mean values of the input distributions and subsequently using the upper 95th percentile values (or for uniform distributions, the maximum values) to estimate the plausible maximum risks to the residents of Deloro. Probabilistic analyses using the assumed probability distributions for the various input variables were also carried out in order to more realistically assess the variability and uncertainty in

the estimated doses and risks.

1.5 REPORT STRUCTURE

The remainder of this report is structured as follows:

Chapter 2, Environmental Media Concentrations, discusses the available environmental radiological data that were obtained from surveys conducted in Deloro, and the resultant media concentrations and ranges used in the assessment. This chapter also describes how the environmental concentrations were estimated when specific media and radionuclides were not measured or when the measured levels were below reporting limits. Finally, this chapter presents information on background radioactivity and radiation levels used in the calculation of background exposures and risks for comparison to the levels and risks estimated for Deloro residents.

Chapter 3, Exposure Factors and Radiation Dose and Risk Factors, describes the basis for the various age-dependent parameters used in the pathways analysis, such as occupancy factors and consumption rates. The radiation dose and risk conversion factors used in the study are also presented.

Chapter 4, Estimates of Radiation Dose and Risk for Deloro Residents, presents the estimates of dose and risk to Deloro residents as a function of zone, age and exposure pathway for both one year and a lifetime of exposure.

Chapter 5, Discussion and Context for Risk Estimates, presents the estimated Deloro risks in comparison to background risks. Sources of uncertainty in the risk estimates, the major contributors to risk and the potential remedial measures for risk reduction are also discussed

Chapter 6, Conclusions, presents the overall conclusions of the radiological health risk assessment.

Appendix A is a brief introduction to radiation and radioactivity to assist those unfamiliar with this subject. Appendix B provides details on the doses and risks estimated in this study. Appendix C describes in more detail the methodology used to calculate dose and risk. Finally, Appendix D provides responses to comments from external reviewers on the preliminary draft (February 1999) of this report.

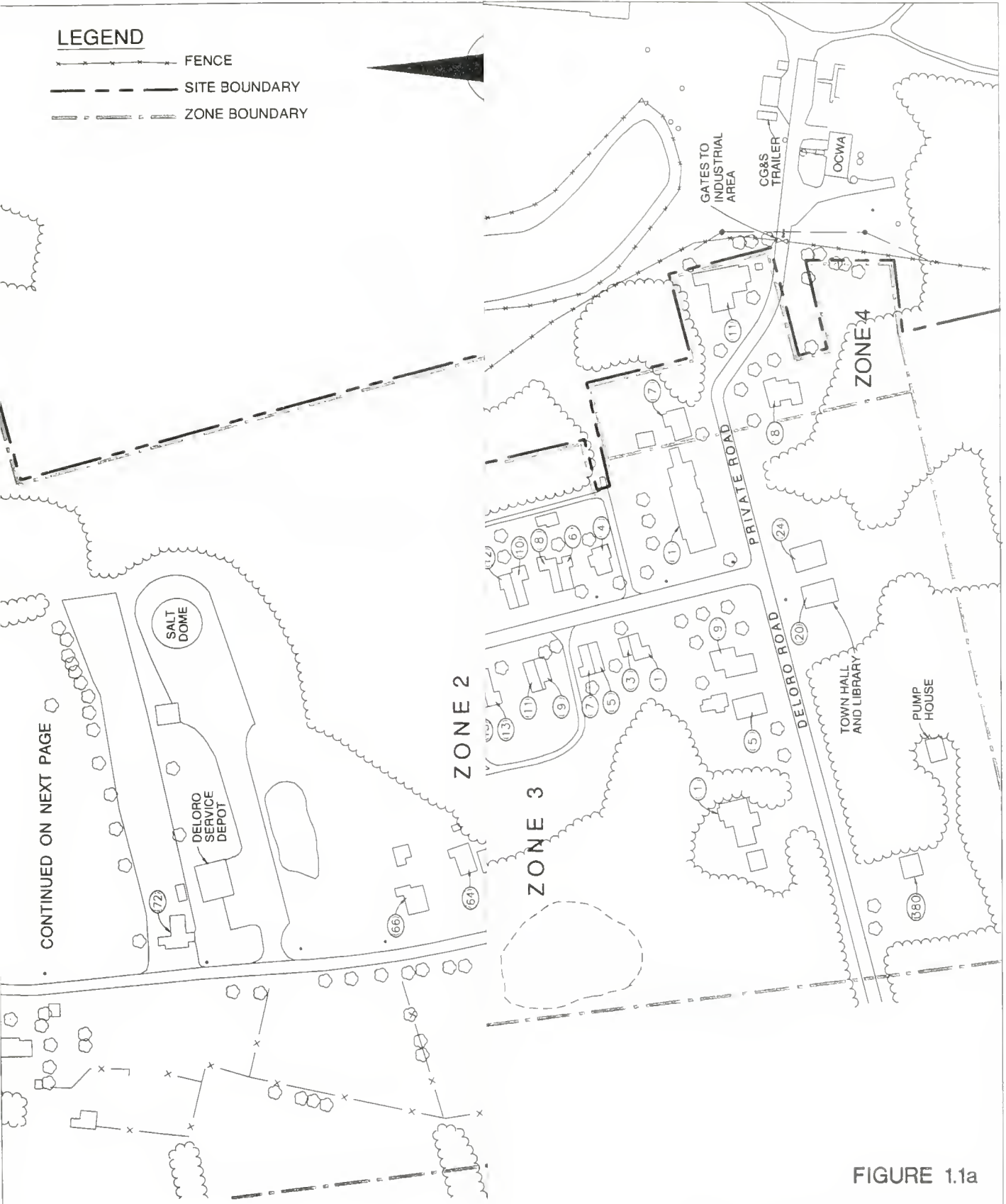

FIGURE 1.1a

VILLAGE OF DELORO ZONE DELINEATION PLAN

FIGURE OBTAINED FROM CH2M GORE & STORRIE LIMITED.

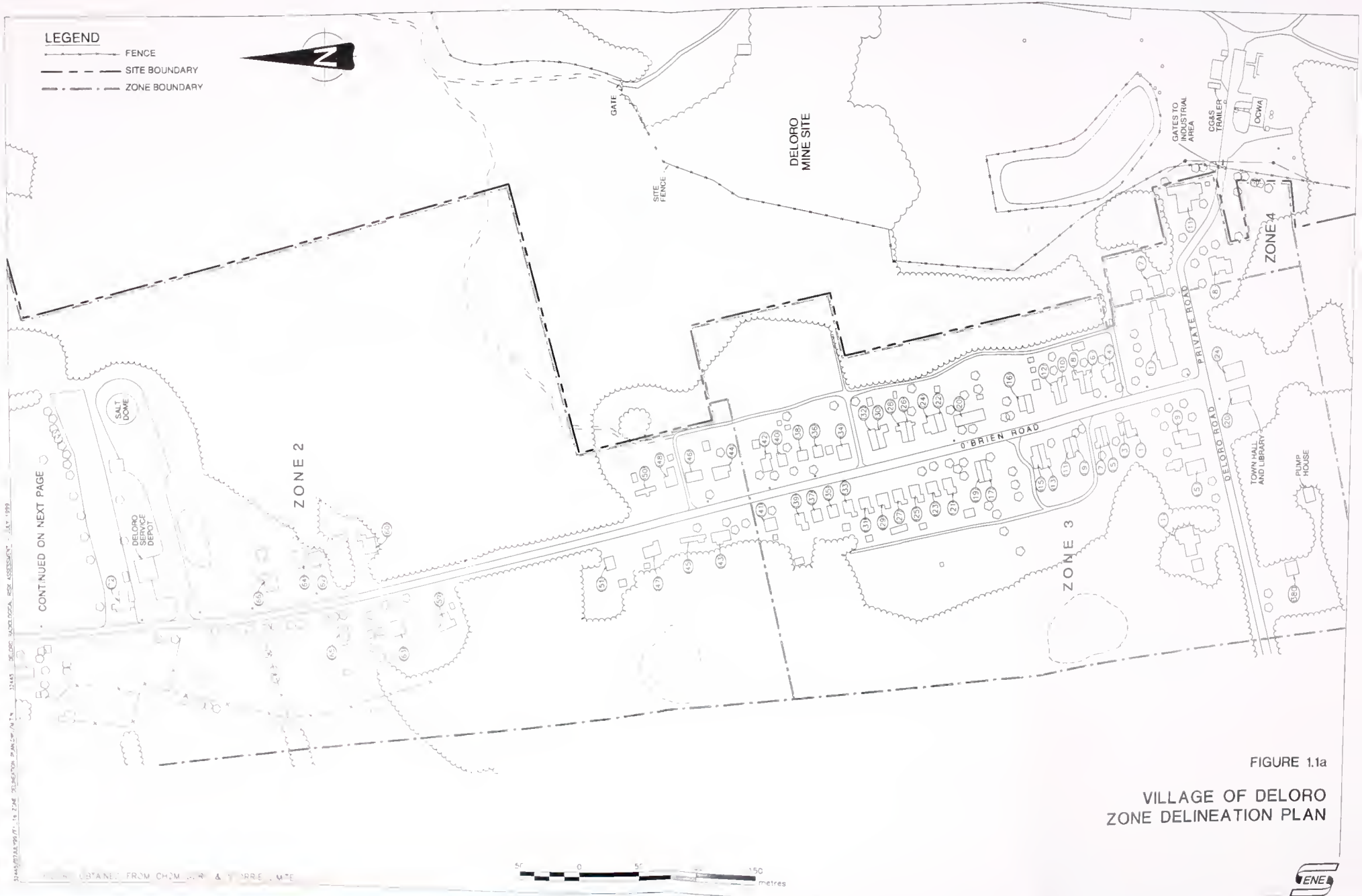

FIGURE 1.1a

VILLAGE OF DELORO
ZONE DELINEATION PLAN

FIGURE 1.1b

VILLAGE OF DELORO
E DELINEATION PLAN

FIGURE OBTAINED FROM CH2M GORE & STORRIE

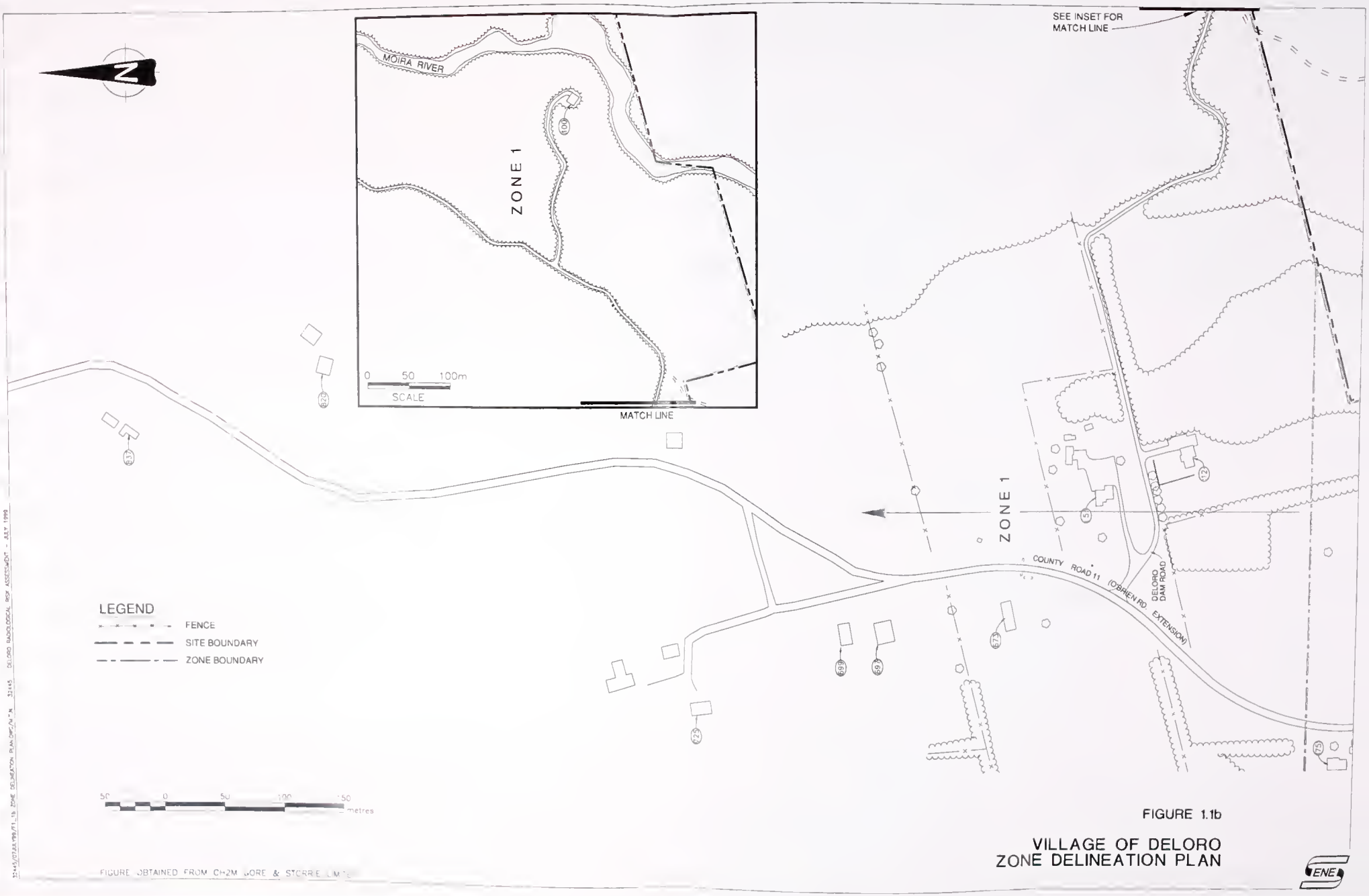

FIGURE OBTAINED FROM CH2M GORE & STORRIE LIMITED

FIGURE 1.1b

VILLAGE OF DELORO
ZONE DELINEATION PLAN

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2.0 ENVIRONMENTAL MEDIA CONCENTRATIONS

Radiological risks arise due to the levels of radiation and radioactivity in the environment in Deloro. Consumption or exposure to these media result in radiological doses. This chapter describes the potential exposure pathways and media considered in this risk assessment and how the radiological levels were measured or estimated.

A comprehensive sampling program was conducted in Deloro and this program provided data for several media that could be used directly in the risk assessment process to describe Deloro conditions. However, in many cases, the measured radiological levels in Deloro were below laboratory reporting limits. Radiological levels in these environmental media were estimated using site-specific measurements of related media and transfer factors that predict concentrations in one media from radiological levels in another media (e.g. garden produce concentrations predicted from soil concentrations).

This chapter presents the mean and plausible maximum concentrations and exposure rates that were used in the deterministic risk assessment and also provides the sampling distributions that were used in the probabilistic analyses.

2.1 MEASURED CONCENTRATIONS IN DELORO

2.1.1 Media and Environmental Parameters Measured

A comprehensive series of environmental surveys were conducted in Deloro during 1998 with the purpose of measuring both chemical radiological levels in environmental media. The following media were investigated to quantify contributions to the radiological risks in Deloro:

- radon (progeny) in air for indoor and outdoor locations;
- external gamma radiation for indoor and outdoor locations;
- airborne dust concentrations indoors and outdoors;
- soil concentrations in yards and gardens;
- water concentrations in municipal and private wells;
- garden produce; and
- dustfall and surface dust.

The measured environmental parameters include radon and terrestrial gamma radiation levels (as described in SENES 1999) and several radionuclides in the uranium decay series, specifically U-238, U-234, Th-230, Ra-226, Pb-210 and Po-210. (Not all samples were measured for all radionuclides.) Additional measurements were made of gross (i.e. total) alpha and gross beta radioactivity levels in some media. Details of the sampling program and analytical results, except for radon and gamma radiation in SENES (1999), are provided in a separate summary report prepared by CG&S (1999).

2.1.2 Radon and Gamma Radiation Levels

Indoor radon levels were measured in each participating household using paired E-PERM radon detectors (as described in SENES 1999). Measurements were taken on two floor levels of each home. In this assessment, the average level of the paired measurement on the first floor was used as the radon level for that home. (Levels tend to be higher in basements and lower in upper floors. The first floor was considered the predominant living space for homes in Deloro.) All indoor radon levels were above an effective reporting limit of 10 becquerels per cubic metre (Bq/m^3). Outdoor radon levels were measured at 9 locations within the town with all but one measured level (immediately adjacent to the former mine site) being below the effective reporting limit of 10 Bq/m^3.

Outdoor gamma radiation levels were, for the most part, measured using automated equipment that collected a high density of measurements on each property (SENES 1999). The average outdoor level for each property was determined from these measurements. Indoor gamma radiation levels were measured during the deployment and retrieval of the radon monitors. Gamma radiation levels were all above reporting limits. The indoor and outdoor gamma radiation measurements on the individual properties in Deloro were used in this assessment.

2.1.3 Soil Radioactivity Levels

Soil samples were collected from the front and back yards of most Deloro residences and were measured for Ra-226 and uranium levels. All uranium levels were above the laboratory reporting limit, with values ranging from about 0.16 to 1.4 ppm (equivalent to about 0.002 to 0.017 Bq U-238/g). The majority of Ra-226 measurements were above the 0.01 Bq/g reporting limit and ranged up to 0.03 Bq/g.

Soil concentrations were also measured for radionuclides not associated with the Deloro site activities and, hence, have not been included in this risk assessment. These radionuclides include the naturally occurring radionuclides K-40, Th-228 and Ra-228, and the Cs-137 originating from atmospheric weapons testing previously conducted around the world. All the Ra-228 measurements were below the 0.05 Bq/g reporting limit. Approximately 40% of the Th-228 measurements were below the 0.02 Bq/g reporting limit. K-40 concentrations were above the reporting limit for all samples. Many (~40%) Cs-137 measurements were above the 0.01 Bq/g reporting limit.

2.1.4 Airborne Dust Concentrations

Outdoor concentrations of airborne dust were measured using hi-volume air samplers. Uranium levels were below the reporting limit (5 µg or 0.06 Bq U-238 per filter) on all 98 outdoor samples analyzed. Measurements above the reporting limit were found for most Pb-210 measurements. Air concentrations above the reporting limit were found for all measurements of Po-210 and some Ra-226 and Th-230, although the Ra-226 and Th-230 levels in the unexposed filters were about equivalent to the exposed filters.

Indoor concentrations of airborne dust were measured using low-volume air samplers designed for sampling occupational airborne dust levels. The measured indoor air concentrations of uranium were all below reporting limits.

2.1.5 Water

In the municipal water supply, the concentrations of uranium (with a reporting limit of 1 ppb, or 0.012 Bq/L of U-238) and all radionuclides were below the reporting limits (0.1 Bq/L for Ra-226, 0.01 Bq/L for Th-230, and Po-210, and 0.5 Bq/L for Pb-210). Ra-226 was measured at or slightly above the reporting limits in two of 15 private wells (0.01 Bq/L reporting limit for these measurements). Th-230 was measured at the reporting limit in two of 10 measurements in the private wells.

Radon levels were not measured in the water samples. However, any such radon (which typically is present in groundwater) would be released to the indoor air during normal household usage. The indoor radon measurements would include any such radon released from the water.

2.1.6 Vegetation Concentrations

Uranium levels were above reporting limits at the garden plots where samples were collected; however, these garden plots tended to have lower soil concentrations for many of the metals than typically measured in the town. There were no radionuclide measurements of vegetation samples.

2.1.7 Dustfall and Dust Swipes

Dustfall measurements provide information on the rate of deposition of dust from the air onto surfaces. Dust swipes provide an estimate of the mass or activity of the material deposited on a surface. These measurements were not used in this risk assessment but potentially provide additional understanding of the radioactivity patterns within Deloro.

Relative to outdoor levels, outdoor dustfall levels (from 10 samples each collected for 30 days) were below reporting limits for uranium, Th-230 and Ra-226; some measurements were at or slightly above the reporting limits (variable) for Po-210 and Pb-210. Swipes of outdoor deposited dust were made both on surfaces and roads. Exterior surfaces were all below the reporting limit for uranium but some road swipes had reportable levels of uranium. Road dust uranium levels ranged from <5 to 11.0 $\mu g/100\ cm^2$, with 11 $\mu g/100\ cm^2$ from a background (non-Deloro) location.

Indoor dustfall measurements had gross alpha levels that were above reporting limits for 30-40% of samples and ranged from <0.01 Bq/154 cm^2 to 0.03 Bq/134 cm^2 with the highest value at an non-Deloro location. Gross beta levels were reported above the reporting limit in about 20% of samples with a limited range from <0.01 Bq/154 cm^2 to 0.02 Bq/154 cm^2. All samples had uranium levels that were below the reporting limit.

Relative to indoor levels, indoor dust swipes were collected from all participating homes and analyzed for gross alpha and gross beta activity. Gross alpha levels reported above the reporting limit of 0.02 Bq/100 cm^2 for about 20% of samples with the values ranging from <0.02 to a maximum of 0.06 Bq/100 cm^2. Gross beta level were above the reporting limit for 50% of the samples with values ranging from <0.02 Bq/100 cm^2 to 0.17 Bq/100 cm^2.

The variation in gross alpha and gross beta measurements from home to home did not necessarily indicate that radioactive contamination was present in homes with the higher gross alpha and beta measurements. Natural radioactivity contributes to gross alpha and beta measurements and the gross alpha and gross beta concentrations are likely more indicative of the quantity of dust collected rather than radioactivity levels in the dust itself.

Specific radionuclide analyses were conducted on a random subset of samples to determine the concentrations of four specific radionuclides in the U-238 decay series. Th-230 activities were below the reporting limit (0.01 Bq) for these samples. Ra-226 activities were all reported below the reporting limit of 0.01 Bq except for one measurement of 0.068 Bq Ra-226 at a background location. Pb-210 activities were mostly above the reporting limit, 0.01 Bq , with higher values at background locations. The most likely reason that Pb-210 activities were elevated relative to other uranium decay series is due to decay of radon progeny.

2.1.8 Measured Concentrations Used in the Risk Assessment

Review of the data indicated that only a limited number of media and concentration levels were generally reported above the reporting limits. The data that were generally above reporting limits and which were used in this assessment include:

- indoor and (some) outdoor radon;
- indoor and outdoor gamma radiation levels;
- soil concentrations of uranium and Ra-226: and,
- outdoor air concentrations of Pb-210 and Po-210.

Media radiological levels were estimated for other media and radiological parameters from these measurements using transfer factors. The procedures used to estimate these levels are described in Section 2.2. Since groundwater levels can not be reasonably estimated from soil or other measured media levels, the water concentration for each radionuclide was conservatively estimated by assuming that it ranged uniformly up to its reporting limit. (The Ra-226 reporting limit of 0.1 Bq/L for the measurement of the municipal water supply was used in this assessment - Tables 2.1, 2.2.)

2.1.9 Deterministic Values and Sampling Distributions

The measured concentrations were used to develop sampling distributions that reflected the range of levels in the environmental media. In most cases, a lognormal distribution was selected to fit the data;

however, normal, uniform and triangular distributions were also used. Lognormal parameters were calculated from the arithmetic mean and arithmetic standard deviation of the data. Uniform distributions were typically used where most, or all, of the measurements were below the reporting limit.

The deterministic assessment determined the doses and risks for mean (average) levels and for maximum plausible concentrations. The mean concentration was set equal to the mean of the sampling distribution. The maximum plausible concentration was set equal to the 95th percentile value for lognormal and normal distributions. For uniform or triangular distributions, the maximum plausible value was set equal to the upper bound of the distribution.

2.1.10 Concentrations by Zone

An overview of the Deloro data, both radiological and chemical, indicated that the Village could be subdivided into four zones. As previously described, Zone 1 is the northernmost part of the Village and is furthest from the former mine site. Zone 2 is a transition area located between the Zone 1 and the core of the Village, Zone 3. Zone 4 is located adjacent to the former mine site entrance.

Environmental data were summarized for each zone and a sampling distribution was assigned to each parameter and medium. Table 2.1 shows these sampling distributions along with the estimated sampling distributions for background conditions.

The mean and plausible maximum values for the probabilistic analyses are presented in Table 2.2. Tables 2.1 and 2.2 provide the measured media concentrations that form the basis for all media concentrations used in this assessment

2.2 ESTIMATED CONCENTRATIONS IN DELORO

As previously noted, the concentrations of radionuclides in many media were below reporting limits. This was also the case for many measurements of chemical (non-radiological) contaminants. This section describes the methodology by which environmental concentrations of the U-238 series radionuclides were estimated when specific media and radionuclides were not measured or when the measured levels were below reporting limits. The U-238 radioactive decay series shown in Figure A.1 may be consulted when reading this section.

2.2.1 Soil Concentrations

The concentrations for the radionuclides of concern in the U-238 series were based on the measurements of uranium and Ra-226 in the Deloro soil samples. The activity concentrations of U-238 and U-234 were assumed to be equal and were based directly on the mass uranium concentrations using the abundance for natural uranium (U-nat) of 0.0123 Bq U-238/g of U-nat. Pb-210 and Po-210 were assumed to be in equilibrium with the long-lived (1600 y) Ra-226.

Although Th-230 is the decay product of U-234, Th-230 concentrations were also assumed to be equal to Ra-226. Because the mean Ra-226 levels exceeded the mean U-238 levels, this latter assumption was adopted to be prudently conservative in this risk assessment.

2.2.2 Outdoor Airborne Dust

As noted, the majority of radiological airborne dust measurements obtained with the high-volume air samplers, with the exception of measurements of Pb-210 and Po-210, were below the limits of detection. (Ra–226 and Th-230 levels were variable and comparable to those in blank, unexposed filters). Airborne concentrations of Pb-210 and Po-210 are typically elevated (by factors of 1000 and 100, respectively) relative to the other radionuclides in the U-238 series because of their formation from atmospheric radon (US. NCRP 1987). The mean measured concentrations of Pb-210 and Po-210 in Deloro, respectively were consistent with nominal background levels of $7x10^{-4}$ and $7x10^{-5}$ Bq/m^3, respectively, suggested for Canada and the United States (U.S. NCRP 1987).

The values measured in Deloro for Pb-210 and Po-210 were used in this assessment. (Po-210 measurements in this assessment were corrected for the decay between sampling and analysis, and for in-growth from Pb-210.) For the other radionuclides, a total suspended particulate (TSP) concentration of 50 µg/m^3 (Section 2.3.7) at the mean Ra-226 concentration of about 0.02 Bq/g for Deloro soil leads to an airborne dust concentration of about $1x10^{-6}$ Bq/m^3 of Ra-226. Because this level is not inconsistent with the Pb-210 level measured in Deloro (i.e. about 1/1000), this procedure (i.e. assumed TSP concentration multiplied by Deloro soil concentrations) was used in this study to estimate both the airborne Ra-226 and Th-230 concentrations from the measured Ra-226 soil concentrations in each zone. Under the same assumption, the U-238 and U-234 airborne concentrations were derived from the uranium soil concentrations in each zone. As shown later in the report, radionuclides in airborne dust contributed very little (<1%) to the estimated doses and risks.

2.2.3 Indoor Airborne Dust

The measurements of radionuclides in indoor airborne dust taken with the low-volume samplers were below the limits of detection in all households sampled. Half the reporting limits were used in reporting the average concentrations in the CG&S (1999) summary report, but the resulting averages were considered inappropriately conservative for use in this analysis because the resulting values were much larger than the outdoor concentrations (due to the much smaller volume of indoor air sampled).

The absence of direct measurements of indoor dust concentrations is not unusual. As often done in radiological risk assessments, indoor air concentrations for this analysis were assumed to be proportional to the outdoor air concentrations.

A wide range of indoor/outdoor airborne dust ratios is reported in the literature. The variation is due to the effects of site-specific conditions, particle size dependency (higher ratio for smaller particles) and the constituent/element being measured. Roberts et al.(1974), in a study of lead contamination in the vicinity of smelters near Toronto, found that indoor airborne dust levels were all from 15% to 30% of the outdoor values. The U.S. NRC (1989), in a study related to assessing public exposures due to a former rare earths facility containing radioactive wastes, used a value of 0.22 (for particles of about 5 micron (μm i.e. 10^{-6} m) in size). Fisenne et al (1996) measured the ratios of indoor to outdoor Pb-210 air concentrations at 0.25 for an office setting and 0.67 for a residential (apartment) setting. The U.S. EPA (1996) reported on a detailed evaluation of indoor to outdoor PM (particulate matter) ratios and concluded that long-term exposures to PM < 10 μm of outdoor origin could be estimated by approximately 50% of the ambient PM. Wilson and Suh (1997) evaluated the variation of the infiltration ratio (indoor PM/outdoor PM) as a function of air exchange rate, with the ratio ranging from about 0.35 to 0.6 for $PM_{(10-2.5)}$ for air exchange rates of 0.5 to 2 per hour, respectively. The ratio ranged up to about 0.8 for $PM_{2.5}$.

Considering the above, and noting that the outdoor measurements in Deloro were for total suspended particulate matter (<50 μm in size), an indoor/outdoor ratio of 0.5 was used in this study. The ratio was assumed to be triangularly distributed about a mean of 0.5, with a range from 0.2 to 0.8.

2.2.4 Indoor Surface Dust

As noted previously, since the swipe samples of indoor dust were below the radioactivity reporting limits, it was necessary to estimate the concentrations in indoor dust from other measurements. Studies on the relationship between outdoor soil arsenic concentrations and indoor dust concentrations reported in Walker and Griffin (1998) indicate that the concentrations in indoor dust were about 40% of the concentrations in outdoor soil. Similar to the indoor/outdoor TSP dust/ratio noted above, the indoor/outdoor soil concentration ratio in this assessment was assumed to be triangularly distributed about a mean of 0.5, with a range from 0.2 to 0.8.

2.2.5 Garden Produce Concentrations and Transfer Factors

Radiological analyses of Deloro home garden produce were not undertaken. As often conventionally dose, the radionuclide concentrations in such produce were estimated using soil concentrations and soil-to-plant transfer factors. In this report, unless otherwise stated, the transfer factors are defined to relate the concentrations in dried soil (as conventionally measured) to the concentration in wet (as consumed) produce.

As noted by Sheppard and Evenden (1988), transfer factors are extremely variable (orders of magnitude) because they are highly dependent on site-specific conditions. As further noted by Sheppard et al. (1989), for the natural radionuclides, such as the isotopes of uranium, thorium, radium and lead of interest to this study, relatively few data in the international literature represent crops and conditions typical of Canada. These issues were discussed in a study undertaken on behalf

of the Low Level Radioactive Waste Management Office (LLRWMO) to derive clean-up criteria for soils in the Port Hope area (SENES 1992). That study used a combination of transfer factors derived by Sheppard et al. (1989) for Port Hope gardens and from previous studies Port Hope gardens (e.g. Tracy et al. 1983). The resultant factors were consistent with those estimated by Sheppard et al. (1989).

For the present study, the transfer factors based on measurements in Port Hope gardens from Sheppard et al. (1989) were used. These were assumed to be more applicable to the Deloro area than values taken from the general literature. The factors are shown in Table 2.3 along with values from Tracy et al. (1983) for comparison. Based on the variability reported in Sheppard et al. (1989) for their Port Hope data (two standard deviations in the log10 values of about 0.4 to 1.3) and the larger uncertainties reported in the generic literature (e.g. IAEA 1994), for present purposes the values in Table 2.3 were assumed to be lognormally distributed with a geometric standard deviation of 3.

With the possible exception of the relatively large value used for Th-230, the transfer factors in Table 2.3 are not inconsistent with the range of more generic published factors (e.g. IAEA 1994). Sheppard et al. (1989) note that most of the recommended values for thorium are tenfold below those for uranium, while their experiments suggest they should be equal or higher as shown in Table 2.3. The transfer factor for Po-210 from Sheppard et al. (1989) was not used because they indicate that they could not differentiate between direct uptake of Po-210 and ingrowth from Pb-210. As explained in SENES (1992), the factor for Po-210 shown in Table 2.3 was derived from the review by Baes et al. (1984).

Although transfer factors can vary significantly among crop types, the factors in Table 2.3 were considered to apply to all types of garden produce, i.e. vegetables and fruits. This was considered somewhat conservative because the measured transfer factors for fruits (usually a smaller fraction of home produce) are generally lower than those for other produce (Sheppard et al. 1989). Notwithstanding the uncertainty in these values, this exposure pathway was found in this study to be a minor contributor (<1%) to the estimates of overall dose and risk.

2.3 Natural Background Radioactivity and Radiation Levels

Estimates of naturally occurring radioactivity and radiation levels (background) were needed for comparison to the dose and risk estimates for Deloro. Many naturally occurring radionuclides have half-lives that are as long or longer than the estimated age of the earth (4.5×10^9 years), and therefore have been present at approximately current levels throughout recent history. They are found throughout our environment – in soil, vegetation, water and air. Some of these radionuclides are members of the uranium-238 series, which is the focus of this report and the following discussion (see also Appendix A). Data on airborne dust mass concentrations (TSP) is also provided since this information was used to estimate concentrations of some airborne radionuclides (Section 2.2.2). A summary of the background levels is provided in Table 2.4.

2.3.1 Radon Concentrations in Indoor and Outdoor Air

Radon (Rn-222) concentrations in both indoor and outdoor air are attributable to radon produced by the decay of Ra-226 in soil. Indoor radon concentrations are typically five to ten times higher than corresponding outdoor levels due to the accumulation of radon within structures.

Outdoor radon concentrations depend on the amount of radon exhaled by soil (the major source) and by atmospheric factors controlling its upward dispersion. With a half-life of 3.8 days, radon can be transported horizontally over great distances by the wind, but vertical movement by diffusion and turbulence dilute the impacts from distant sources.

Relative to outdoor concentrations, Grasty (1994) measured radon concentrations in outdoor air across Canada in the summer of 1990, and reported that the averages in Ottawa, Toronto and Sudbury were 16, 6 and 11 Bq/m^3, respectively (Table 2.4) (U.S. NCRP 1987). For comparison, the mean radon concentrations in outdoor air in New York State were reported from several studies at 4 to 9 Bq/m^3. In areas such as Colorado Springs, Colorado and Cincinnati, Ohio where higher rates of radon exhalation from soil are observed (due to soil conditions, and/or Ra-226 concentrations), mean outdoor radon concentrations of 44 and 18 Bq/m^3, respectively, have been reported (U.S. NCRP 1987). For this analysis, a uniform distribution from 6 to 16 Bq/m^3 based on the results of Grasty (1994) was used for the outdoor radon levels.

Indoor radon concentrations have been observed over a very wide range due to the variability of controlling factors such as porosity of foundations and adjacent backfill, ventilation rates, leak-tightness to outside air, and Ra-226 concentrations in adjacent soil. The local outdoor radon concentration contributes directly to the indoor concentrations through ventilation, but is usually only a minor component.

During the spring and fall of 1976, radon progeny measurements in indoor air (grab samples) were made in 68 homes in Deloro. The mean radon progeny concentration was reported to be 6 milliworking levels (mWL), and the standard deviation was 3.3 mWL (Knight and Makepeace 1980). About 13% of the houses exceeded 20 mWL. The 6 mWL corresponds to about 45 to 75 Bq/m^3 depending on the equilibrium fraction (0.3 to 0.5) assumed for radon progeny. However, the radon progeny concentrations in some of these homes were considered to be potentially impacted by radon from local waste materials (from the former mine site) containing Ra-226. To provide a basis for comparison to natural background levels, radon measurements made in approximately 100 homes in Cobourg, considered an unimpacted area, were also reported. The mean of the radon concentrations was given as approximately 18 Bq/m^3 (average of summer and fall measurements). Corresponding radon progeny concentrations were calculated to have a mean value of 1.5 mWL (standard deviation of 0.1 mWL), assuming a radon equilibrium fraction of 0.3 (Knight and Makepeace 1980). None of the about 100 houses sampled were calculated to exceed 20 mWL for radon progeny. Cobourg, however, is on Lake Ontario, and would tend to have lower concentrations than inland locations such as Deloro.

Health Canada conducted a large survey of radon concentrations in homes (about 10,000) in major cities across Canada during the summers of 1977 and 1978 (McGregor et al. 1980, U.S. NCRP 1987). The geometric means of the different cities varied from 5.2 to 32.6 Bq/m^3 for radon and 0.9 to 3.6 mWL for radon progeny. The arithmetic mean indoor concentration for homes in the city of Toronto was 20 Bq/m^3 (the closest site to Deloro), and the mean radon progeny concentration was 2.8 mWL (as reported in U.S. NCRP 1987). The mean indoor radon and radon progeny concentrations in Sudbury, which like Deloro is located on the Canadian Shield, were reported at 86 Bq/m^3 and 6.6 mWL, respectively. These however were also grab samples with the location in each home selected to produce maximum values, i.e. often the basement.

In the United States, the National Residential Radon Survey was conducted during 1989 and 1990 (Marcinowski et al. 1994). For single family detached homes, the geometric mean annual concentration was reported as 29.2 Bq/m^3 (mean = 54 Bq/m^3) with a geometric standard deviation of 2.97. The measured concentrations were approximately lognormally distributed, and in 7% of the homes, the radon concentrations exceeded 148 Bq/m^3, the U.S. EPA's action level for remediation.

In summary, the historical data on indoor radon specific to Deloro were considered to have possibly been impacted by waste materials. The Cobourg data may be biased low (relative to Deloro) because it is on Lake Ontario and the Health Canada cross-Canada data were obtained under maximized conditions. Therefore, for this assessment, the background indoor radon concentration was based on the U.S. survey and was assumed to be lognormally distributed with a nominal geometric mean of 30 Bq/m^3 and geometric standard deviation of 3 (arithmetic mean = 54.85 Bq/m^3).

2.3.2 Concentrations of Other Uranium-238 Series Radionuclides in Air

Airborne particulate radioactivity is attributable to resuspension of radioactivity from the soil, exhalation of radioactive gases from soil, and creation of radioactivity in the air from cosmic radiation.

Direct measurements of the concentrations of long-lived uranium series radionuclides in air (U-238, U-234, Th-230 and Ra-226) are not common. Based on the few data available, U.S. NCRP (1987) recommends that a reasonable natural background value (attributable mainly to resuspended soil) is 0.7 μBq/m^3.

The longer-lived decay products of radon, Pb-210 and Po-210, are largely formed in the atmosphere from the decay of radon but their half-lives are sufficiently long (22 years and 134 days, respectively) that they have a separate existence from the parent radon. Upon their production in air, they attach to particles of ambient aerosol, which control their behaviour in the atmosphere and during inhalation. Reported Pb-210 concentrations in continental United States range from 300 to 1500 μBq/m^3 and the recommended representative concentration is 0.7 mBq/m^3 (U.S. NCRP 1987). A value of 0.07 mBq/m^3 is recommended as representative of the natural background concentration

of Po-210 in air (U.S. NCRP 1987). For this assessment, the background concentrations of Pb-210 and Po-210 were assumed to be lognormally distributed about these values (taken as geometric means) and with geometric standard deviations of 2.

2.3.3 Concentrations in Soil

The LLRWMO (1997) reported on the distribution of Ra-226 in Ontario soils with mean (median) values ranging from 0.019 (0.019) Bq/g to 0.03 (0.025) Bq/g in six MOE regions. The arithmetic and geometric mean concentrations from MOE Region 4 (which includes Deloro and Hastings County) were reported at 0.024 and 0.023 Bq/g, respectively, and 97.5% of the samples measured contained less than 0.044 Bq/g (LLRWMO 1997). These values are lower than the results of measurements of Ra-226 in surface soils taken across the area in Ontario bounded by Burlington, Lake Simcoe and Rice Lake. The Geological Survey of Canada reported that the mean concentration of Ra-226 in surface soils was 0.033 Bq/g, and the 98th percentile was 0.052 Bq/g (as referenced in STF 1994).

For comparison, Myrick et al. (1983) measured the U-238 and Ra-226 concentrations in approximately 350 surface soil samples from 33 states in the United States, and reported mean concentrations of 0.037 and 0.041 Bq/g, respectively. In Ohio and New York, states adjacent to Ontario, U-238 concentrations at 0.052 and 0.035 Bq/g, respectively, were reported.

Based on the LLRWMO (1997) data for MOE Region 4, the natural background concentrations of uranium series radionuclides in surface soils were assumed in this analysis to be normally distributed with an arithmetic mean of 0.024 Bq/g and a standard deviation of 0.007 Bq/g. This corresponds to mean uranium mass concentration of 1.94 ppm.

2.3.4 Concentrations in Garden Produce

The radioactivity in vegetation derives from the radioactivity in soil or water from which the vegetation derives nutrients through roots systems.

Tracy et al. (1983) carried out a study of radionuclide transfer from soil to produce in Port Hope gardens. Concentrations of total uranium, Ra-226 and Pb-210 were measured in soils and produce from both control (natural background) and impacted gardens. Based on the results of analyses of radionuclide concentrations in a wide variety of leafy and root vegetables, and fruits, Tracey et al. reported the geometric mean concentrations of total uranium, Ra-226 and Pb-210 in background produce (from control gardens) at 0.31 µg/kg, 0.10 Bq/kg and 0.079 Bq/kg fresh weight, respectively. As previously noted for this analysis (Section 2.2.5), the radioactivity of garden produce was estimated from the soil concentrations and assumed soil-to-plant transfer factors. The Port Hope data are within about a factor of 3 of background concentrations estimated in this manner.

2.3.5 Concentrations in Drinking Water

Both surface water and ground water are utilized as sources of drinking water in Ontario. Natural background levels of radionuclides have been measured in water taken from Dunlop Lake and Elliot Lake water supply stations in July 1993 (SENES and NEA 1994). These lakes, situated on the Canadian Shield, are considered by the AECB, MOE and others to be baseline lakes in terms of water quality. The measurement ranges in four samples were: Th-230 (<5 to 7 mBq/L); Ra-226 (20 to 54 mBq/L); Pb-210 (<50 mBq/L); Po-210 (6 to 13 mBq/L) and uranium (<0.5 to 0.8 µg/L). As previously noted (Section 2.1.5), concentrations in Deloro water supplies were generally below reporting limits. For this assessment, all water sources (Deloro and background) were assumed to have a mean of one-half the reporting limits for the Deloro samples and to range uniformly up to reporting limits for each radionuclide (Tables 2.1, 2.2).

2.3.6 External Radiation Dose (Outdoors and Indoors)

While outdoors, radiation doses to people from external sources are attributable to terrestrial sources of naturally occurring radioactivity and cosmic radiation. Compared to outdoor doses, indoor doses are increased by radioactivity in building materials, and decreased by shielding of outdoor sources by building materials. Thus, indoor dose rates may be above or below corresponding outdoor dose rates depending on local factors.

Outdoor external radiation dose rates are measured on a continuous basis at selected sites across Canada by the Health Canada monitoring network. Tracy et al (1996) reported that the annual average absorbed dose to tissue at these sites is 76 nGy/h (averaged over the two-year 1993-1994 period), ranging over a factor of about two from 62 nGy/h at Coral Harbour on Southampton Island in Hudson Bay to 103 nGy/h at Digby, Nova Scotia. These values include a contribution from cosmic radiation of approximately 30 nGy/h. (Note that 1 nGy/h dose to tissue is approximately equivalent to 0.1 µR/h exposure.) The reported annual average dose rates at the centres closest to Deloro were 73 and 79 nGy/h at two sites in Ottawa (about 7.6 µR/h), and 64 nGy/h at Toronto (about 6.4 µR/h). Seasonal variations at the various sites were in the order of $\pm$20% of the mean at each site.

Grasty et al. (1984) report on airborne summer measurements of terrestrial gamma radiation across Canada. (As noted in U.S. NCRP (1987), these exposure rates may have been underestimated by about 10%.) The measurements range from about 2 to 3 µR/h to about 10 to 12 µR/h or higher, with measurements in Ontario regions closest to Deloro ranging from about 3 to 8 µR/h. Based on these data for Ontario which are not inconsistent with those of Tracy et al. (1996), the outdoor background gamma radiation exposure rate for this assessment was assumed to be uniformly distributed from 3 to 8 µR/h. These estimates of terrestrial gamma radiation exposure rates, which do not include cosmic radiation, were used as background because the exposure rates in Deloro (SENES 1999) were measured predominantly with detectors (scintillometers) that are insensitive to cosmic radiation.

Documentation of measurements of indoor dose rates in Canada was not found during preparation

of this report. Indoor dose rates are often estimated by multiplying outdoor dose rates by the ratio of indoor to outdoor dose rates measured elsewhere. Grasty et al. (1984) suggested indoor/outdoor ratios of 0.9 to 1.3 for woodframe and apartment buildings, respectively.

The average indoor absorbed dose rates in air were measured in 80 houses in New York State and New York City (U.S. NCRP 1987). The results ranged from an average of 27 nGy/h inside frame houses to an average of 46 nGy/h inside masonry houses. Based on these measured values, the distribution of indoor exposure rates used in this assessment was assumed to be uniform, ranging from 3.0 to 5.3 μR/h. This is consistent with the assumed outdoor exposure rates.

2.3.7 Total Suspended Particulate (TSP) Concentrations in Air

As previously noted, estimated TSP concentrations were used to estimate airborne concentrations of uranium, Th-230 and Ra-226 from the measured soil concentrations. (The Pb-210 and Po-210 airborne concentrations were based on the measurement in Deloro.) The Ontario Ministry of the Environment (MOE) carries out regular measurements of the concentrations of airborne particulate material at numerous locations throughout Ontario. Although there are no monitoring stations in the MOE network located at Deloro, annual average airborne particulate concentrations are likely comparable to corresponding values measured in nearby rural areas.

The annual average concentration of total suspended particulate (dust less than approximately 50 μm) at the nearest MOE station, Dorset, was reported in the range 13 to 17 $\mu g/m^3$ during the period 1993 to 1995 (e.g. MOEE 1995). During the same period, the annual average PM-10 concentrations in air (inhalable particulate <10 mm) at Toronto, Cornwall and Sudbury (the nearest MOE stations) were reported at 23 to 27, 22 to 23 and 16 to 23 $\mu g/m^3$ during the same period. Analysis of the results of airborne particulates from the Canadian National Air Pollution Surveillance (NAPS) network revealed that on average across all 19 sites, PM2.5 accounted for 49% of the PM10, and PM10 accounted for 44% of the TSP (Brook et al 1997).

TSP concentrations in the order of 50 to 100 $\mu g/m^3$ are often used in risk assessments. Because of lower measured values in Dorset, an annual average TSP (<50 μm dust) value of 50 $\mu g/m^3$ was conservatively assumed in this assessment for Deloro. This was used to estimate concentrations of airborne radionuclides (except for the measured Pb-230 and Pb-210 concentrations). This is conservative for inhalable (<10 μm) dust.

Table 2.1

Sampling Distributions for Deloro Media Concentrations and Exposure Rates [a]

Medium	Analyte	Units	Zone 1	Zone 2	Zone 3	Zone 4	All Deloro	Background
Indoor Air	Gamma(indoor)	µR/h	LN(4.69,0.916)	LN(4.637,0.631)	LN(5.113,1.004)	LN(5.705,0.276)	LN(4.985,0.933)	U(3, 5.3)
Indoor Air	Radon(indoor)	Bq/m^3	LN(85.54,86.47)	LN(45.06,37.55)	LN(49.94,46.56)	LN(161.4,143.8)	LN(56.58,58.52)	LN(54.85,83.97)
Outdoor Air	Gamma(outdoor)	µR/h	LN(6.081,0.567)	LN(5.842,0.508)	LN(6.973,0.481)	LN(8.925,1.009)	LN(6.713,0.861)	U(3, 8)
Outdoor Air	Pb-210	mBq/m^3	LN(0.474,0.377)	LN(0.582,0.443)	LN(0.628,0.476)	LN(0.661,0.575)	LN(0.602,0.456)	LN(0.743,0.266)
Outdoor Air	Po-210	mBq/m^3	U(0, 0.06)	LN(0.026,0.016)	LN(0.025,0.017)	U(0, 0.042)	LN(0.025,0.013)	LN(0.074,0.027)
Outdoor Air	Radon(outdoor)	Bq/m^3	U(0, 10)	U(0, 10)	U(0, 10)	LN(13.5,12.02)	LN(6.545,5.126)	U(6, 16)
Soil	Ra-226	Bq/g	LN(0.016,0.008)	LN(0.018,0.006)	LN(0.018,0.006)	LN(0.016,0.007)	LN(0.017,0.006)	N(0.024,0.007)
Soil	Uranium	ppm	LN(0.314, 0.06)	LN(0.335,0.079)	LN(0.385, 0.15)	LN(0.596,0.448)	LN(0.376,0.161)	N(1.943,0.567)
Water	Pb-210	Bq/L	U(0, 0.5)	U(0, 0.5)	U(0, 0.5)	U(0, 0.5)	U(0, 0.5)	U(0, 0.5)
Water	Po-210	Bq/L	U(0, 0.01)	U(0, 0.01)	U(0, 0.01)	U(0, 0.01)	U(0, 0.01)	U(0, 0.01)
Water	Ra-226	Bq/L	U(0, 0.1)	U(0, 0.1)	U(0, 0.1)	U(0, 0.1)	U(0, 0.1)	U(0, 0.1)
Water	Th-230	Bq/L	U(0, 0.01)	U(0, 0.01)	U(0, 0.01)	U(0, 0.01)	U(0, 0.01)	U(0, 0.01)
Water	U-234	Bq/L	U(0, 0.012)	U(0, 0.012)	U(0, 0.012)	U(0, 0.012)	U(0, 0.012)	U(0, 0.012)
Water	U-238	Bq/L	U(0, 0.012)	U(0, 0.012)	U(0, 0.012)	U(0, 0.012)	U(0, 0.012)	U(0, 0.012)

Notes:

a. LN(u,std) specifies lognormal distribution with u = arithmetic mean, std = arithmetic standard deviation.
N(u,std) specifies normal distribution with u = arithmetic mean, std = arithmetic standard deviation.
U(min,max) specifies uniform distribution with range of values from min to max.

Table 2.2

Deloro Mean and Plausible Maximum Media Concentrations and Exposure Rates

Medium	Analyte	Units	Zone 1	Zone 2	Zone 3	Zone 4	All Deloro	Background
Indoor Air	Gamma(indoor)	µR/h	4.69 (6.328)	4.637 (5.741)	5.113 (6.909)	5.705 (6.17)	4.985 (6.648)	4.15 (5.3)
Indoor Air	Radon(indoor)	Bq/m^3	85.54 (239.2)	45.06 (114.3)	49.94 (134.2)	161.4 (423.7)	56.58 (160)	54.85 (182.8)
Outdoor Air	Gamma(outdoor)	µR/h	6.081 (7.056)	5.842 (6.714)	6.973 (7.791)	8.925 (10.67)	6.713 (8.215)	5.5 (8)
Outdoor Air	Pb-210	mBq/m^3	0.474 (1.173)	0.582 (1.409)	0.628 (1.516)	0.661 (1.715)	0.602 (1.452)	0.743 (1.238)
Outdoor Air	Po-210	mBq/m^3	0.03 (0.06)	0.027 (0.056)	0.025 (0.057)	0.021 (0.042)	0.025 (0.05)	0.074 (0.124)
Outdoor Air	Radon(outdoor)	Bq/m^3	5 (10)	5 (10)	5 (10)	13.5 (35.43)	6.545 (16.07)	11 (16)
Soil	Ra-226	Bq/g	0.016 (0.031)	0.018 (0.029)	0.018 (0.029)	0.016 (0.029)	0.017 (0.028)	0.024 (0.036)
Soil	Uranium	ppm	0.314 (0.421)	0.335 (0.479)	0.385 (0.666)	0.596 (1.433)	0.376 (0.678)	1.943 (2.876)
Water	Pb-210	Bq/L	0.25 (0.5)	0.25 (0.5)	0.25 (0.5)	0.25 (0.5)	0.25 (0.5)	0.25 (0.5)
Water	Po-210	Bq/L	0.005 (0.01)	0.005 (0.01)	0.005 (0.01)	0.005 (0.01)	0.005 (0.01)	0.005 (0.01)
Water	Ra-226	Bq/L	0.05 (0.1)	0.05 (0.1)	0.05 (0.1)	0.05 (0.1)	0.05 (0.1)	0.05 (0.1)
Water	Th-230	Bq/L	0.005 (0.01)	0.005 (0.01)	0.005 (0.01)	0.005 (0.01)	0.005 (0.01)	0.005 (0.01)
Water	U-234	Bq/L	0.006 (0.012)	0.006 (0.012)	0.006 (0.012)	0.006 (0.012)	0.006 (0.012)	0.006 (0.012)
Water	U-238	Bq/L	0.006 (0.012)	0.006 (0.012)	0.006 (0.012)	0.006 (0.012)	0.006 (0.012)	0.006 (0.012)

Note: Plausible maxima shown in parentheses.

Table 2.3

Soil-to-Plant Transfer Factors for Home Gardens

Transfer factor[a]					
Uranium	Th-230	Ra-226	Pb-210	Po-210	Reference
7.50E-05	-	1.10E-03	3.70E-04	-	Tracy et al. (1983)
5.30E-04	1.90E-03	1.80E-03	1.40E-03	1.50E-04	Sheppard et al. (1989), Baes et. al. (1984), and used in this study[b, c]

Notes:

a. All values are given on a plant (fresh wet) to soil (dry weight) concentration basis.
b. Values (geometric means) from Sheppard et al. (1989, Table 7) have been multiplied by a nominal 0.1 to convert to a fresh-weight basis, based on data in Table 12 of Sheppard et al.(1989). The values were assumed to be lognormally distributed with a geometric standard deviation of 3 (see text).
c. Po-210 value abstracted from Baes et al. (1984) as reported in SENES (1992).

Table 2.4

A Selected Summary of Natural Background Radioactivity and Radiation Levels

Medium	Radioactive Species	Units	Concentrations[a]					Comments (see text)
			AM	ASD	GM	GSD	Range	
Air	Radon (Rn-222) outdoor air	Bq/m^3					6-16 4-9	at Ottawa, Toronto and Sudbury New York State
	Radon (Rn-222) indoor air	Bq/m^3	18 20 86		 11 21 29.2	 2.8 4.0 2.97		100 homes in Cobourg Toronto homes Sudbury homes U.S. National Residential Radon Surve
	Rn-222 progeny indoor air	mWL	1.5 2.8 6.6	0.1	 1.8 3.6	 2.6 3.0		100 homes in Cobourg Toronto homes Sudbury homes
	U-238, U-234, Th-230, Ra-226 Pb-210 Po-210	$\mu Bq/m^3$ mBq/m^3 mBq/m^3					0.7 0.7 0.07	Recommended value in U.S., Canada each member of the series U.S. data U.S. data
	TSP[b] PM10	$\mu g/m^3$					13-17 16-23	At Dorset, Ontario Toronto, Conrwall, Sudbury
Soil	Ra-226 U-238	Bq/g	0.023 0.033 0.041 0.037		0.024			MOE Region 4 Burlington to Rice Lake 33 U.S. States 33 U.S. States
	Garden produce: Ra-226 U Pb-210	 Bq/kg $\mu g/kg$ Bq/kg			 0.10 0.31 0.079		 +.028,-.021 +.17,-.11 +.028,-.021	Fresh weight Port Hope garden: 68% confidence limit 68% confidence limit 68% confidence limit
Drinking Water	Th-230 Ra-226 Pb-210 Po-210 Uranium	mBq/L $\mu g/L$					<5-7 20-54 <50 6-13 <0.5 to 0.8	Dunlop and Elliot Lake water supplies
Outdoors	External radiation	nGy/h[c]	76 73,79 63				62-103	Across Canada Ottawa Toronto
		$\mu R/h$					3-8	Ontario
Indoors	External radiation	nGy/h					27-46	80 houses in New York State and New York City

Notes:

a. AM = arithmetic mean
ASD = arithmetic standard deviation
GM = geometric mean or median
GSD = geometric standard deviation.

b. TSP = total suspended particulate
PM10 = particulate matter <10 µm in size.

c. Absorbed dose to tissue (1 nGy/h - 0.115 µR/h).

3.0 EXPOSURE FACTORS AND RADIATION DOSE AND RISK FACTORS

3.1 EXPOSURE FACTORS

The following general protocol was used to obtain information (data) on exposure factors used in the exposure pathways analyzed. As recommended by the MOE, the first source used to obtain exposure factors for this study was Canadian data compiled by Richardson (1997). In the absence of any Canadian data, studies summarized by the U.S. EPA were used since it was considered that the U.S. and Canadian populations are somewhat similar.

For deterministic calculations, the arithmetic mean of the distribution used in the probabilistic assessment was used as the mean. A plausible maximum was calculated based on the 95th percentile of the data distribution (or the maximum value if the distribution were uniform). If published distributions were available that described the data, they were used in the assessment.

In order to reflect the Canadian population, the following age ranges were used:

- 7 months – 4 years, reflected by a 1 yr old;
- 5 years – 11 years reflected by a 5 yr old at the lower end of the range and a 10 yr old at the upper end;
- 12 – 19 years, reflected by a 15 yr old; and
- an adult 20+ years old.

Some of the age ranges were not reflected in the published literature data (for example soil/dust ingestion rates) and thus scientific judgement was used in developing the distributions used in this report. Typically, for parameters that were not well defined, a uniform distribution was used. Bounds for these uniform distributions were based on the examination of data in the above references and generally were the mean and the plausible maximum.

3.1.1 Water Intakes

Data on consumption of water were obtained from Richardson (1997). The data all follow a lognormal distribution pattern. Table 3.1 summarizes the data used in this assessment. For younger children, the Canadian data do not reflect the appropriate age ranges used in this assessment. Thus Richardson (1997) used data from Ershow and Cantor (1989) for children and adolescents. For a 1 year old, the typical consumption rate was 0.6 L/d whereas children in the 5 – 11 year age group consume slightly more at 0.8 L/d. Adolescents consumed 1 L/d and adults 1.5 L/d.

3.1.2 Soil/Dust Ingestion

For soil ingestion, the U.S. EPA (1997) recommends a mean value of 100 mg/d and an upper bound of 400 mg/d for children. Thompson and Burmaster (1991) recommend the use of a lognormal

distribution with a mean value of 91 mg/d with a standard deviation of 126 mg/d. The MOE in their risk assessments generally use a mean ingestion rate of 80 mg/d for children (e.g. MOEE 1994). Based on discussions with the MOE and the study team, the MOE recommended mean value (80 mg/d) for children was adopted in this assessment. A lognormal distribution was used to describe the data with a standard deviation of 126 mg/d since it was assumed that the distribution of the data is similar between Canadian and American children. For adults, a mean value of 50 mg/d is recommended by the U.S. EPA. However, the MOE use a mean value of 20 mg/d for adults. A uniform distribution was used to describe this data, with the minimum boundary conservatively set at the mean value of 20 mg/d and a maximum value of 100 mg/d (resulting mean of 60 mg/d). Table 3.2 summarizes the soil/dust ingestion data used in this assessment. The intakes were divided into intakes of indoor and outdoor material in proportion to the amount of time spent indoors and outdoors (Section 3.1.6).

3.1.3 Air Inhalation Rates

The inhalation rates for the various age groups were obtained from Richardson (1997). These data were described by lognormal distributions and are shown in Table 3.3. Typical mean values ranged from 9.3 m^3/d for the 1 year old to 15.8 m^3/d for an adult.

3.1.4 Consumption Rate of Local Garden Produce

From Richardson (1997), the mean total daily consumption rate of fruits and vegetables is 570 g/day (208 kg/y) for adults (245 g/day fruit, 325 g/day vegetables) and 527 g/day (192 kg/y) for 5 - 11 y old children (268 g/day fruit, 259 g/day vegetables). Values are also indicated for other age groups as shown in Table 3.4. However, only a portion of this intake would be from home gardens, especially since the intake of fruits includes fruit juices, much of which is commercially produced. The fraction of the total intake of fruits and vegetables assumed to come from home gardens was estimated as follows.

Assuming an average garden size of 30 m^2, an average yield of 1.4 kg/m^2 (CSA 1987) would result in 42 kg/y of home produce, or 10.5 to 14 kg/y per person for a typical family size of 3 to 4 people. In a study by Tracy et al. (1983) that measured the transfer of radionuclides from soil to home garden produce in Port Hope, a dietary survey of home gardeners participating in the study found consumption rates ranging from 1.5 to 34 kg/y per person, for a mean of about 20 kg/y per person. This range of intakes (10.5 to 20 kg/y) from home gardens is about 5% to 10% of the total consumption rate of fruits and vegetables noted above.

For this analysis, a mean value of 7.5% of the total consumption of fruits and vegetables for each of the age groups was assumed to come from home gardens. The value was assumed to range uniformly from 0% (some Deloro residents do not have home gardens) to 15% (to preserve the mean of 7.5%).

3.1.5 Exposure to Gamma Radiation and Radon

Exposures to gamma radiation and radon progeny were based on the time spent indoors and outdoors in Deloro. (Section 3.2.1 discusses the relationship between radon and radon progeny levels.)

3.1.6 Activity Patterns (Time Spent Indoors and Outdoors)

The times a resident spends indoors or outdoors at Deloro were obtained from the survey of Deloro residents conducted in 1998 by Goss Gilroy Inc. (1999). These values are presented in Table 3.5 for both the summer and winter seasons. The values obtained from this survey are similar to the mean values of 115 hours/week for time spent indoors and 14 hours/week for time spent outdoors published by the U.S. EPA (1997). For this assessment, a uniform distribution with bounds between the reported mean value and the plausible maximum was conservatively used to describe this data.

3.2 Radiation Dose and Risk Conversion Factors

In this assessment, the radiation doses from both internal (to the body) and external exposures via all potentially significant exposure pathways were estimated and summed to arrive at the total radiation dose to the receptors (people) under consideration. The resultant doses were then multiplied by appropriate risk factors to estimate the resultant risks. This study addressed potential radiological doses and risks only; chemical doses and risk, which can in some circumstances be more restrictive for uranium exposures, were not part of this analysis.

For the internal exposures, this required that the intakes of radioactivity by inhalation and ingestion, measured in units of becquerels (Bq), be converted to dose, measured in units of sieverts (Sv) or millisieverts (mSv). Inhalation of radon and its progeny is a special case as discussed below. The potential intake of radioactivity by dermal (through the skin) absorption was considered insignificant relative to other exposure pathways for the radionuclides studied in this assessment.

For the external exposures, this required that the exposure or exposure rate at the receptors locations, measured in this assessment in the historical units of roentgen (R) or microroentgen (μR or 10^{-6} R), be converted to dose.

The bases for the dose conversion factors (DCFs) and risk conversion factors used in this assessment are described below.

3.2.1 Dose Conversion Factors

3.2.1.1 Internal Exposures

The inhalation and ingestion DCFs used in this assessment are shown in Table 3.6. These are taken from Publication 72 of the International Commission on Radiological Protection (ICRP 1996). The

general recommendations of the ICRP on radiation protection issues (ICRP Publication 60, 1991), including the ICRP DCFs, are widely accepted and used in many countries of the world, including in Canada by Health Canada, the Atomic Energy Control Board and other federal and provincial agencies.

Before examining the DCFs in Table 3.6, it should be noted that radionuclides irradiate the body even after intakes have ceased. The duration of irradiation depends on many factors, including the radioactive and biological half-lives of the radionuclides and decay products within the body. The ICRP uses a respiratory tract model and biokinetic models, based on available metabolic data specific to each radionuclide, to estimate the distribution of radionuclides throughout the body following intake by inhalation or ingestion. The ICRP DCFs are given in terms of the committed dose per unit intake, that is, the cumulative dose to be received over the next 70 years (a lifetime) following intake (over the next 50 years for adults). For radiation protection purposes, the committed dose is assigned to the year of intake. In this way, even for a lifetime of continuous exposure, the actual dose received in any given year will not be underestimated.

Inhalation DCFs

Relative to intakes by inhalation (for radionuclides other than radon and its decay products), the DCFs depend on particle size, inhalation type, and age at exposure. The ICRP DCFs in Table 3.6 for environmental exposures of members of the public are based on the ICRP default activity median aerodynamic diameter (AMAD) of 1 micron (μm, or 10^{-6} m); that is, the size of the airborne particulate is assumed to be lognormally distributed, and to have a median diameter of 1 μm. This is considered by the ICRP to be an appropriate size for typical environmental exposures, although some data indicate that resuspended particulate matter such as wind suspended soils tends to be larger, in the order of 5 to 7 μm (e.g. Dorrian 1996). DCFs for 5 μm AMAD particles would be smaller (but within a factor of 2) for the radionuclides shown in Table 3.6, except for Pb-210 (about 12% larger for adults (ICRP Publication 68, 1994)).

The ICRP classifies inhaled particles as (S)low, (M)oderate and (F)ast depending on the rate of clearance of the particles from the lung to other parts of the body. The inhalation type depends on the chemical form (solubility) of the particle within the lungs. Generally, since the lung is a relatively sensitive organ in terms of radiation exposures, the longer the particles remain in the lungs, the greater the dose received by the lung. (This is the case for all radionuclides in Table 3.6, except for Th-230. Once transferred from the lungs, the Th-230 is relatively immobile and remains in the skeleton essentially over the lifetime of the individual.) In the absence of specific information, the ICRP default is type M for the radionuclides shown in Table 3.6, except for thorium, for which the default is type S. In order not to underestimate potential doses, the inhalation DCFs selected for this assessment assumed S type particles for all radionuclides.

Natural uranium also contains the U-235 series of radionuclides (at about 5% the activity of U-238) that can in some circumstances have a substantial impact on estimated inhalation doses (Lowe 1997).

However, for the inhalation DCFs (S type particles) used in this assessment, the contribution from the U-235 series is not radiologically significant relative to the U-238 series (< 10%). The contribution of the U-235 series to ingestion doses is even smaller.

As shown in Table 3.6, the inhalation DCFs decrease with age at exposure. This is because the lower organ masses of children result in higher doses per unit intake of radioactivity.

Radon

The inhalation of radon and its progeny is a special case. The potential risks from exposure to radon are actually associated with its short-lived decay products. Radon (3.8 day half-life) is an inert gas that does not remain in the lungs for sufficient time to cause significant exposures under typical environmental conditions. However, the short-lived decay progeny of radon (effective half-lives of about one-half hour) are solids that attach to particulate matter and the respiratory tract when inhaled. The progeny release alpha particles that irradiate the lungs. Radon progeny typically contribute to 50% or more of natural background radiation dose.

Exposure to radon progeny is measured in terms of working level months (WLM), where 1 WLM is the exposure to 1 working level (WL) of radon progeny for 170 hours (defined as a working month). The WL is a measure of the concentration of radon progeny in air and is equivalent to a concentration of approximately 3700 Bq/m^3 of radon in radioactive equilibrium with its progeny. The degree of equilibrium between radon and its progeny depends on a number of parameters, including the age or residence time of the air. Typical indoor equilibrium values in Canada and the United States are in the order of 0.4 (U.S. NCRP 1987), the value used in this assessment. This means that 3700 Bq/m^3 of radon in indoor air is equivalent to 0.4 WL. Typical indoor radon levels (50 Bq/m^3) result in annual exposures of about 0.2 WLM.

Outdoor radon concentrations (typically in the range of about 5 to 20 Bq/m^3) are generally much lower than indoor concentrations and depend on the amount of radon exhaled by soil and the atmospheric factors controlling its dispersion. The typical outdoor equilibrium factor of 0.7 (U.S. NCRP 1987) is however larger than typical indoor values. This is because radon derives from soil across the continent and is dispersed with the wind currents. The time from release of radon from the ground to the time the radon reaches any given location can be large and thus the time for radon progeny ingrowth can also be large. For local radon sources, the travel time is short and hence the equilibrium factor which reflects the degree of ingrowth would be smaller for local sources. The 0.7 value was used in this study to convert outdoor radon concentrations to concentrations of radon progeny (in WL), and then ultimately to exposure (WLM) and dose. This value is considered conservative for any radon emitted locally (such as from the Deloro mine site) because outdoor air at any location includes both "young" radon and "old" radon that originated at distant locations. For example, for an average windspeed of 4 m/s, the age of the radon at a 1 km distance from a radon source would be 250 s, and the corresponding radon equilibrium factor would be only about 0.08 (based on Evans 1969). The radon measurements in Deloro refer to total radon, comprising both

background radon and any radon emitted from the Deloro site and any contaminated soils in the area.

The ICRP (1993) has issued a report that presents its most recent recommendations on the limitation of exposure to radon and progeny at home and at work. The ICRP report summarizes information about the health effects of exposure to radon and considers that the use of epidemiological studies, rather than dosimetric modelling as used for other radionuclides, is the best approach to quantifying the risks of radon exposure. From the large number of available epidemiological studies on uranium and other miners, the ICRP derives conversion factors for both workers and members of the public to convert exposure to radon progeny to radiation doses.

The ICRP (1993) dose conversion factor for members of the public is:

$$1\,WLM = 4\,mSv$$

The ICRP (1993) examined the issue of the age-dependence of exposure to radon progeny and concluded that it knows of no reason to adopt a lifetime risk coefficient for children different from that for adults. This ICRP-recommended value was used in this assessment for estimating the doses to all age groups resulting from exposure to radon and its progeny. (As discussed by Lowe and Chambers (1996), a published meta-analysis of major epidemiological studies (in which the results of the studies are combined) suggests that a lower dose conversion factor of 1 to 3 mSv per WLM might be more appropriate for members of the public.)

Ingestion DCFS

Relative to intakes by ingestion, the DCFs depend on the uptake of the ingested material to the body and the age at exposure. The uptake to the body is measured in terms of f_1, the gut-to-blood transfer fraction. The f_1 values shown in Table 3.6 are the ICRP default values, the only values given in ICRP Publication 72 (1996). These values are considered by the ICRP to be appropriate when evaluating environmental exposures of the public.

Similar to the inhalation DCFs, the ingestion DCFs decrease with age at exposure.

3.2.1.2 External Exposures

External exposure in this assessment refers to gamma radiation exposure. External exposures by alpha and beta particles irradiate only the skin, not the more radiation-sensitive internal body organs. (External beta irradiation of the eyes can be a potential concern in some occupational settings.) Because of the self-shielding provided by the body, the dose from gamma radiation depends on the gamma energy and the geometry of the irradiation. Higher gamma energies produce higher doses. Irradiation from the front of the body (anterior) produces more dose than irradiation from the back (posterior)

A working group from Health Canada, the Atomic Energy Control Board and Atomic Energy of

Canada that was formed to review parameters used in dose assessments in Canada examined the effect of age and gender on external dose coefficients (Health Canada 1999). The group noted that a modifying factor of 1.5 that was used to increase adult external dose coefficients when applied to younger age groups was very conservative for some radionuclides and age groups. The group recommended that more appropriate factors could be calculated if the specific nuclides were known. The working group also chose not to recommend a correction factor based on gender.

Saito et al. (1998) have calculated the effective dose from environmental gamma radiation sources using the latest ICRP dosimetric methodology. They assessed the variation of the effective dose with energy, irradiation geometry and body size (age), with body size having the largest influence on the dose. Their results are expressed in units of sieverts (Sv) per gray (Gy) in air, where 1 R = 0.00876 Gy. For irradiation by ground-based U-238 series radionuclides (the radionuclides of concern to this assessment), the calculated effective doses were 0.672, 0.766 and 0.899 Sv/Gy for an adult, child (7 y old) and infant (8 wk), respectively.

For this assessment, the nominal effective doses for other ages of interest were approximated by interpolating the results from Saito et al. (1998). The resulting dose conversion coefficients for gamma radiation are shown in Table 3.7. Given that the difference in the effective doses between an adult and an infant is about 33%, it is unlikely that the effective dose estimates in Table 3.7 are in error by more than about 10% to 15% for each age group.

3.2.2 Risk Conversion Factors

The ICRP (1991) has derived nominal values of risk to be used for radiation exposures of both workers and members of the public. The risk factors apply to low dose, low-dose rate exposures such as are relevant to this assessment. For members of the public, the risk factor for cancer is 0.06 Sv^{-1}, comprising 0.05 Sv^{-1} for fatal cancers and 0.01 Sv^{-1} for non-fatal cancers. These values are averages over both sexes and all ages (0 to 90 y) of the whole population, and were assumed in this study to apply to adults. (Non-stochastic, i.e. threshold effects, do not occur at the radiation exposures relevant to this assessment.)

The age at exposure is of relatively great importance because of the risk projection model used by the ICRP. Age-dependent risk factors have become available in recent years, although there is still considerable uncertainty in the factors. The risk factor (for fatal cancer) for children and adolescents per unit effective dose is larger than the risk factor for the whole population, by about a factor of 2.9 for ages 0 – 9 y and by a factor of 1.7 for ages 10 – 19 y (Almen and Matsson 1996). These age adjustments were used in this assessment. As noted above, for adults, the ICRP risk factor averaged over all ages was used, a conservative assumption. Since the risk of non-fatal cancers is considered by the ICRP to be proportional to the risk of fatal cancers, it was assumed that these age variations also apply to the total cancer risk. The resultant radiation risk conversion factors used in this study are shown in Table 3.8.

The factors in Table 3.8 refer to the risk of total cancer, the same end-point that is conventionally used when estimating the risks of exposure to non-radiological (chemical) exposures. The ICRP (1991) has also estimated a risk factor for hereditary effects that is about 20% of the risk factor for cancer. The ICRP genetic risk estimates are under review, and the information to date implies that future estimates of genetic risk from radiation will be lower than those in current use (Griffith 1999). Furthermore, no evidence of any significant increase in genetic or partially genetic defects has ever been observed in any group of irradiated humans that has been studied, including the children of the atomic bomb survivors (ACRP 1996). For these reasons, and to be consistent with the assessment of non-radiological risk for Deloro, genetic effects were not considered in this study.

Table 3.1

Summary of Drinking Water Intake Rates (L/d) Used in This Assessment

Age (years)	Deterministic Mean	Deterministic Plausible Maximum	Probabilistic Distribution[a]	Reference
1	0.6	1.35	LN (0.6,0.4)	Richardson (1997)
5	0.8	1.56	LN (0.8,0.4)	Richardson (1997)
10	0.8	1.56	LN (0.8,0.4)	Richardson (1997)
15	1	2.13	LN (1.0,0.6)	Richardson (1997)
Adult	1.5	3.01	LN (1.5,0.8)	Richardson (1997)

Table 3.2

Summary of Soil/Dust Ingestion Rates (mg/d) Used in This Assessment

Age (years)	Deterministic Mean	Deterministic Plausible Maximum	Probabilistic Distribution[a]	Reference
1	80	270	LN (80,126)	Thompson and Burmaster (1991) and MOE
5	80	270	LN (80,126)	Thompson and Burmaster (1991) and MOE
10	80	270	LN (80,126)	Thompson and Burmaster (1991) and MOE
15	60	100	U (20,100)	MOE
Adult	60	100	U (20,100)	MOE

Notes:

a. LN (μ, std) = lognormal distribution with μ = arithmetic mean and std = arithmetic standard deviation.
U (min, max) = uniform distribution with range from min to max.

Table 3.3

Summary of Inhalation Rates (m^3/d) Used in This Assessment

Age (years)	Deterministic Mean	Deterministic Plausible Maximum	Probabilistic Distribution[a]	Reference
1	9.3	14.1	LN (9.3,2.6)	Richardson (1997)
5	14.5	20.3	LN (14.5,3.2)	Richardson (1997)
10	14.5	20.3	LN (14.5,3.2)	Richardson (1997)
15	15.8	23.1	LN (15.8,4)	Richardson (1997)
Adult	15.8	22.9	LN (15.8,3.9)	Richardson (1997)

Table 3.4

Summary of Ingestion Rates of Garden Produce (g/d) Used in This Assessment

Age (years)	Type of Produce	Deterministic Mean	Deterministic Plausible Maximum	Probabilistic Distribution[a]	Reference
1	Fruit	234	579	LN (234,186)	Richardson (1997)
	Root Veges.	105	272	LN (105,91)	
	Other Veges.	67	195	LN (67,74)	
5	Fruit	268	699	LN (268,236)	Richardson (1997)
	Root Veges.	161	425	LN (161,145)	
	Other Veges.	98	288	LN (98,110)	
10	Fruit	268	699	LN (268,236)	Richardson (1997)
	Root Veges.	161	425	LN (161,145)	
	Other Veges.	98	288	LN (98,110)	
15	Fruit	258	688	LN (258,237)	Richardson (1997)
	Root Veges.	227	560	LN (227,179)	
	Other Veges.	120	354	LN (120,136)	
Adult	Fruit	245	618	LN (245,202)	Richardson (1997)
	Root Veges.	188	468	LN (188,151)	
	Other Veges.	137	370	LN (137,129)	

Note:

a. LN (μ, std) = lognormal distribution with μ = arithmetic mean and std = arithmetic standard deviation.

Table 3.5

Summary of Activity Patterns (h/wk) Used in This Assessment

Age (years)	Place - Season	Deterministic Mean	Deterministic Plausible Maximum	Probabilistic Distribution[a]	Reference
1	Indoors - Summer	125	129	U (121,129)	Goss Gilroy (1999)
	Outdoors –Summer	22.4	26.3	U (18.4,26.3)	
	Indoors – Winter	135	135	single-valued	
	Outdoors - Winter	12.3	12.3	single-valued	
5	Indoors - Summer	110	121	U (98,121)	Goss Gilroy (1999)
	Outdoors –Summer	20.2	26.3	U (14,26.3)	
	Indoors – Winter	119	135	U (103,135)	
	Outdoors - Winter	10.8	12.3	U (9.3,12.3)	
10	Indoors - Summer	110	121	U (98,121)	Goss Gilroy (1999)
	Outdoors –Summer	20.2	26.3	U (14,26.3)	
	Indoors – Winter	119	135	U (103,135)	
	Outdoors - Winter	10.8	12.3	U (9.3,12.3)	
15	Indoors - Summer	103.4	121	U (85.8,121)	Goss Gilroy (1999)
	Outdoors –Summer	19.3	26.3	U (12.2,26.3)	
	Indoors – Winter	112.5	135	U (89.9,135)	
	Outdoors - Winter	10.2	12.3	U (8.17,12.3)	
Adult	Indoors - Summer	107.4	129	U (85.8,129)	Goss Gilroy (1999)
	Outdoors –Summer	15.3	18.4	U (12.2,18.4)	
	Indoors – Winter	112.5	135	U (89.9,135)	
	Outdoors - Winter	10.2	12.3	U (8.17,12.3)	

Note:

a. U (min, max) = uniform distribution with range from min to max.

Table 3.6

Radiation Dose Conversion Factors (Inhalation and Ingestion) for Members of the Public [a]

Radionuclide	Inhalation DCFs (Sv/Bq)						Ingestion DCFs (Sv/Bq)					
		age						age				
	Type [b]	1 year	5 years	10 years	15 years	adult	f_1 [c]	1 year	5 years	10 years	15 years	adult
U-238	**S**	**2.5E-05**	**1.6E-05**	**1.0E-05**	**8.7E-06**	**8.0E-06**	0.02	**1.2E-07**	**8.0E-08**	**6.8E-08**	**6.7E-08**	**4.5E-08**
	M [d]	9.4E-06	5.9E-06	4.0E-06	3.4E-06	2.9E-06						
U-234	**S**	**2.9E-05**	**1.9E-05**	**1.2E-05**	**1.0E-05**	**9.4E-06**	0.02	**1.3E-07**	**8.8E-08**	**7.4E-08**	**7.4E-08**	**4.9E-08**
	M [d]	1.1E-05	7.0E-06	4.8E-06	4.2E-06	3.5E-06						
Th-230	**S** [d]	**3.5E-05**	**2.4E-05**	**1.6E-05**	**1.5E-05**	**1.4E-05**	5.0E-04	**4.1E-07**	**3.1E-07**	**2.4E-07**	**2.2E-07**	**2.1E-07**
	M	7.4E-05	5.5E-05	4.3E-05	4.2E-05	4.3E-05						
Ra-226	**S**	**2.9E-05**	**1.9E-05**	**1.2E-05**	**1.0E-05**	**9.5E-06**	0.2	**9.6E-07**	**6.2E-07**	**8.0E-07**	**1.5E-06**	**2.8E-07**
	M [d]	1.1E-05	7.0E-06	4.9E-06	4.5E-06	3.5E-06						
Pb-210	**S**	**1.8E-05**	**1.1E-05**	**7.2E-06**	**5.9E-06**	**5.6E-06**	0.2	**3.6E-06**	**2.2E-06**	**1.9E-06**	**1.9E-06**	**6.9E-07**
	M [d]	3.7E-06	2.2E-06	1.5E-06	1.3E-06	1.1E-06						
Po-210	**S**	**1.4E-05**	**8.6E-06**	**5.9E-06**	**5.1E-06**	**4.3E-06**	0.5	**8.8E-06**	**4.4E-06**	**2.6E-06**	**1.6E-06**	**1.2E-06**
	M [d]	1.1E-05	6.7E-06	4.6E-06	4.0E-06	3.3E-06						

Notes:

a. DCFs taken from ICRP Publication 72 (1996). DCFs used in this study shown in **bold**.
b. DCFs for 1 μm AMAD particles (ICRP default) and ICRP inhalation types (S)low and (M)oderate.
c. f_1 = ICRP gut-to-blood transfer fraction.
d. ICRP recommended default inhalation type in the absence of specific information.

Table 3.7

Dose Conversion Coefficients for Gamma Radiation from U-238 Series Radionuclides in the Ground

Age	Coefficients (Sv/Gy(air)) [a]	(Sv/R) [b]
1 year	0.85	0.0074
5 years	0.80	0.0070
10 years	0.73	0.0064
15 years	0.70	0.0061
adult	0.672	0.0059

Notes:

a. Based on Saito et al. (1998) - see text.
b. Based on 1 R = 0.00876 Gy (air).

Table 3.8

Radiation Risk Conversion Factors

Age	Risk Factor (Sv^{-1}) [a]
1 year	0.17
5 years	0.17
10 years	0.10
15 years	0.10
adult	0.06

Note:

a. Total cancer incidence - see text.

4.0 ESTIMATES OF RADIATION DOSE AND RISK FOR DELORO RESIDENTS

4.1 DOSE FROM ONE YEAR OF EXPOSURE

The calculated radiation doses from 1 year of exposure are summarized in Table 4.1 by zone within Deloro and for background radiation. The calculated doses are further categorized by age at exposure and by major pathway: gamma, radon, water, other and total. The doses shown in Table 4.1 are probabilistic and were derived from the distributions of input parameters as described previously. Both arithmetic mean values and the upper 95th percentile values are shown.

Figures 4.1 and 4.2 show the frequency histograms and cumulative probability functions of annual dose calculated for the Deloro 1 year old and adult groups, respectively. Various descriptive statistics are also provided. Finally, descriptive statistics for the annual dose from background radiation levels are also shown for purposes of comparison on Figures 4.1 and 4.2.

Several observations are suggested:

- The highest annual dose occurs to the 1 year old, although total doses to all age groups differ by 40% or less within each zone.
- Exposures to radon and gamma radiation are the major contributors to dose.
- The doses estimated for the water pathway were identical for all zones and background because the same concentrations were used for all locations.
- Annual doses to people in Zone 4 (closest to the former mine site) are highest followed by doses to people in Zone 1. This is primarily due to the radon pathway.
- The range (mean to 95th percentile) of predicted doses for all Deloro is within the range of doses calculated for background exposures.

4.2 LIFETIME DOSE AND RISK ESTIMATES

The approach to estimating lifetime risks is described earlier in this report. In essence, these are the risks that accrue to an individual who spends his or her entire life in Deloro. In simple terms, this is done by calculating the annual dose in each life stage as described previously, multiplying by the number of years in the life stage and in turn multiplying by age dependent factors to convert dose to risk over remaining years of life. The lifetime risk is then estimated by summing the risks estimated for each life stage. Details of these calculations and results are given in Appendices B and C.

As discussed previously, two kinds of results were estimated. The first are deterministic results arising from the use of single values for the input parameters. These results are presented in Appendix B for estimates arising from the use of the mean values of the input parameter distributions and from using the upper 95th percentile values of the input distributions to estimate a plausible upper bound risk. It should be noted that overall, this approach is likely to result in very conservative overestimates of the actual risk as the calculation compounds the conservatisms present in each of

the individual parameters. Second, results are presented for the probabilistic analysis in which the probability distributions for each of the input distributions are sampled with the intention of capturing the natural variability within a particular category or parameter. The results of such an analysis are interpreted as probability distributions of lifetime risk, that is, lifetime risk from a lifetime of living in Deloro Village. The results can be used to calculate the normal statistical descriptors such as mean, median, and percentiles.

The probabilistic results can also be used in sensitivity analyses to help identify those parameters which contribute most to the risk or the most to the variability in the risk. In addition to variability, further uncertainty in the estimated risks arises from imperfect understanding of the exposure pathways, media concentrations or human exposure factors. These topics, are discussed in Chapter 5.

Tables showing the detailed lifetime risk and dose estimates are provided in Appendix B for:

- the Village of Deloro as a whole;
- each of the four zones that were designated to investigate how doses and risks might vary with location relative to the mine site; and
- the assumed levels of natural background radiation.

In considering these results, it is important to remember that the estimates of risk for residents of Deloro were based on estimates of dose which reflect the total dose consisting of contributions from natural background and whatever increment above natural background might be attributable to local contamination. Appendix B contains tables of risks estimated with both deterministic methods and probabilistic methods. Deterministic results are presented for calculations using means of the input distributions and for the plausible maximum values. The tables for the probabilistic results report both the mean value estimated for lifetime risk and the upper 95th percentile of risk for each of the above categories. The estimated risks for both deterministic analysis and probabilistic analysis are further subdivided by exposure pathway.

Additional results are shown in Appendix B for the deterministic and probabilistic evaluations. For deterministic calculations, the ratio of plausible maximum to mean is reported. For the probabilistic results, the ratio of the upper 95th percentile risk to the mean risk is reported. In addition, for both deterministic and probabilistic analyses, the ratio of the risk (by pathway and total over all pathways) of the risk for a zone divided by the risk arising from the assumed natural radiation background is reported. Several observations are apparent:

Deterministic Results

- The mean values from the deterministic analyses are comparable to the mean values from the probabilistic analyses.

- The ratios of the plausible maximum values to the mean values from the deterministic mean

values can be quite large and are consistently much larger than the ratios of the 95th percentiles to the mean values from the probabilistic analyses. This is a direct reflection of the effect of compounding conservatisms in the estimation of plausible maximum values.

- The estimated risks from the deterministic analysis (which always include background) were above a screening threshold of $1x10^{-5}$ for all pathways and thus were all carried forward to the probabilistic analyses for further consideration.

Probabilistic Results

Table 4.2 summarizes the probabilistic estimate of risk. Figure 4.3 shows the predicted distribution of risk for lifetime residency in Deloro. The results indicate the following:

- The ratio of the upper 95th percentile to the mean is generally in the range of 2 to 3, typical of environmental data.

- The range (mean to 95th percentile) of the overall risk for all of Deloro is within the estimated range of risk from background exposures.

- An elevation in gamma radiation dose and risk is indicated for Zone 4 closest to the mine site. The source of the gamma radiation increment is likely to be in part due to the "shine" from materials located on or near the mine site.

- The risks from radon show a slight increase from that calculated for the assumed natural background in both Zone 4 closest to the mine site and in Zone 1 furthest from the mine site. This suggests that the radon levels are likely due to variation in natural background as opposed to being related to ambient radon from the mine site.

Figure 4.3 shows the results of the probabilistic analysis for the Village as a whole. This figure shows the probability distribution for the lifetime risk predicted for all residents in Deloro, as well as a cumulative probability histogram for the same data. The 50th percentile (median) risk, the average risk, and the upper 95th percentile risk are also shown on the figure. For comparison, the same statistics for the risks estimated for from natural background are also shown. Overall, the lifetime risk for lifetime residents of Deloro are comparable to those from natural background.

4.3 Doses and Risks From Casual On-Site Access

Some Deloro residents occasionally spend time on the former mine site itself and there is potential for above-background radiological risk from these activities. This exposure scenario is highly dependent on individual habits that are not reflective of general exposure conditions within Deloro itself, the prime focus of this study. As a result, based on discussions with the study team, on-site exposures and risks were evaluated independently of other exposure scenarios.

Elevated gamma radiation fields and elevated concentrations of uranium and Ra-226 are present at several on-site locations. Radiological levels in two areas where the residents may spend time were provided (SCIMUS Inc. 1999). The two areas were the industrial area located adjacent to the southeast portion of the Village (at the mine site fence) and Young's Creek located several hundred metres away from the western fenceline at the southern portion of the site on the east side of the Moira River. These areas, which tended to have the highest gamma exposure levels, were thought to be more likely to be visited by Deloro residents than other areas (SCIMUS Inc. 1999).

Gamma radiation exposure rates averaged 74 and 109 μR/h in the industrial and Young's Creek areas, respectively. The overall average gamma radiation level was 91 μR/h based on the assumption of equal time spent in both areas. This radiation level is about 15 times higher than the typical radiation levels measured outdoors on residential properties in Deloro.

Based on discussions with the MOE and the study team, it was assumed that Deloro residents might spend an average over the entire year of ½ h per day for 4 days per week (104 hours per year) in these areas. (This was considered to be an average over all age groups). On this basis, doses from gamma radiation exposures were estimated to range from 5.6×10^{-5} Sv/y to 7.0×10^{-5} Sv/y for the different age groups. The resulting estimated lifetime risk attributable to gamma radiation exposures was about 3×10^{-4}. This is less than about 5% of the mean risks estimated both for all of Deloro and for background exposures (Table 4.2).

As noted, elevated soil concentrations also exist in the Young's Creek and the industrial areas so there is also potential for exposures resulting from soil ingestion and inhalation of airborne dust. However, Young's Creek is a damp area so the rate of suspension of soils to airborne dust is likely lower than in other areas. Also, most of the radioactivity in the industrial area is concentrated in slags so ingestion or suspension to airborne dust is unlikely (SCIMUS Inc. 1999). On this basis, a screening analysis that conservatively assumed radioactive equilibrium of the entire U-238 series with Ra-226, indicated that soil ingestion and airborne dust exposures are negligible (less than about 10%) compared to the gamma radiation levels. Exposures while on the site to any radon emitted from the site would also be negligible because the ingrowth of radon progeny on the site would be extremely small (see Section 3.2).

Table 4.1

Probabilistic Estimates of Doses (Sv) from One Year of Exposure as a Function of Zone, Age and Exposure Pathway

Zone and Age	Gamma Radiation Mean	Gamma Radiation 95th	Radon Mean	Radon 95th	Water Mean	Water 95th	Other Mean	Other 95th	Total Mean	Total 95th
All Deloro										
1 year	2.8E-04	3.6E-04	9.7E-04	2.8E-03	2.1E-04	5.6E-04	2.4E-05	5.4E-05	1.5E-03	3.3E-03
5 years	2.5E-04	3.3E-04	9.0E-04	2.6E-03	1.7E-04	4.2E-04	2.0E-05	4.5E-05	1.3E-03	3.1E-03
10 years	2.3E-04	3.0E-04	9.0E-04	2.5E-03	1.5E-04	3.6E-04	1.4E-05	3.3E-05	1.3E-03	3.0E-03
15 years	2.0E-04	2.6E-04	8.3E-04	2.4E-03	2.0E-04	5.4E-04	1.3E-05	2.9E-05	1.2E-03	2.8E-03
Adult	2.0E-04	2.6E-04	8.5E-04	2.4E-03	1.1E-04	2.8E-04	9.6E-06	2.2E-05	1.2E-03	2.7E-03
Zone 1										
1 year	2.7E-04	3.5E-04	1.5E-03	4.1E-03	2.2E-04	5.9E-04	2.1E-05	5.0E-05	2.0E-03	4.5E-03
5 years	2.4E-04	3.1E-04	1.3E-03	3.7E-03	1.8E-04	4.5E-04	1.7E-05	4.1E-05	1.8E-03	4.1E-03
10 years	2.2E-04	2.8E-04	1.3E-03	3.6E-03	1.5E-04	3.7E-04	1.2E-05	2.7E-05	1.7E-03	4.1E-03
15 years	1.9E-04	2.5E-04	1.2E-03	3.5E-03	2.1E-04	5.4E-04	1.1E-05	2.6E-05	1.6E-03	3.8E-03
Adult	1.8E-04	2.5E-04	1.3E-03	3.5E-03	1.1E-04	2.6E-04	8.1E-06	1.9E-05	1.6E-03	3.8E-03
Zone 2										
1 year	2.6E-04	3.1E-04	7.7E-04	2.0E-03	2.2E-04	5.9E-04	2.5E-05	5.7E-05	1.3E-03	2.5E-03
5 years	2.3E-04	2.8E-04	7.1E-04	1.8E-03	1.7E-04	4.3E-04	2.0E-05	4.7E-05	1.1E-03	2.2E-03
10 years	2.1E-04	2.6E-04	7.1E-04	1.8E-03	1.5E-04	3.7E-04	1.4E-05	3.2E-05	1.1E-03	2.2E-03
15 years	1.9E-04	2.3E-04	6.6E-04	1.7E-03	2.0E-04	5.2E-04	1.3E-05	3.0E-05	1.1E-03	2.1E-03
Adult	1.8E-04	2.3E-04	6.7E-04	1.7E-03	1.1E-04	2.7E-04	9.8E-06	2.2E-05	9.7E-04	2.1E-03
Zone 3										
1 year	2.9E-04	3.7E-04	8.3E-04	2.2E-03	2.2E-04	5.7E-04	2.5E-05	5.7E-05	1.4E-03	2.8E-03
5 years	2.6E-04	3.4E-04	7.7E-04	2.1E-03	1.8E-04	4.2E-04	2.1E-05	4.8E-05	1.2E-03	2.6E-03
10 years	2.4E-04	3.1E-04	7.7E-04	2.0E-03	1.5E-04	3.8E-04	1.5E-05	3.2E-05	1.2E-03	2.4E-03
15 years	2.1E-04	2.8E-04	7.1E-04	1.9E-03	2.1E-04	5.7E-04	1.3E-05	3.1E-05	1.1E-03	2.3E-03
Adult	2.0E-04	2.7E-04	7.2E-04	1.9E-03	1.1E-04	2.7E-04	1.0E-05	2.3E-05	1.0E-03	2.2E-03
Zone 4										
1 year	3.3E-04	3.6E-04	2.7E-03	6.7E-03	2.2E-04	6.0E-04	2.6E-05	6.2E-05	3.2E-03	7.4E-03
5 years	3.0E-04	3.3E-04	2.4E-03	6.2E-03	1.7E-04	4.2E-04	2.2E-05	5.5E-05	2.9E-03	6.7E-03
10 years	2.7E-04	3.0E-04	2.5E-03	6.2E-03	1.5E-04	3.5E-04	1.5E-05	3.7E-05	2.9E-03	6.7E-03
15 years	2.4E-04	2.7E-04	2.3E-03	5.8E-03	2.1E-04	5.5E-04	1.4E-05	3.4E-05	2.7E-03	6.2E-03
Adult	2.3E-04	2.6E-04	2.3E-03	6.0E-03	1.1E-04	2.7E-04	1.1E-05	2.8E-05	2.7E-03	6.3E-03
Background										
1 year	2.3E-04	2.9E-04	9.3E-04	3.0E-03	2.2E-04	5.9E-04	3.5E-05	6.3E-05	1.4E-03	3.7E-03
5 years	2.1E-04	2.6E-04	8.6E-04	2.8E-03	1.8E-04	4.3E-04	2.9E-05	5.2E-05	1.3E-03	3.2E-03
10 years	1.9E-04	2.4E-04	8.6E-04	2.8E-03	1.5E-04	3.6E-04	2.0E-05	3.6E-05	1.2E-03	3.2E-03
15 years	1.7E-04	2.1E-04	7.9E-04	2.6E-03	2.1E-04	5.4E-04	2.1E-05	4.2E-05	1.2E-03	3.0E-03
Adult	1.6E-04	2.1E-04	8.1E-04	2.6E-03	1.1E-04	2.6E-04	1.4E-05	2.5E-05	1.1E-03	2.9E-03

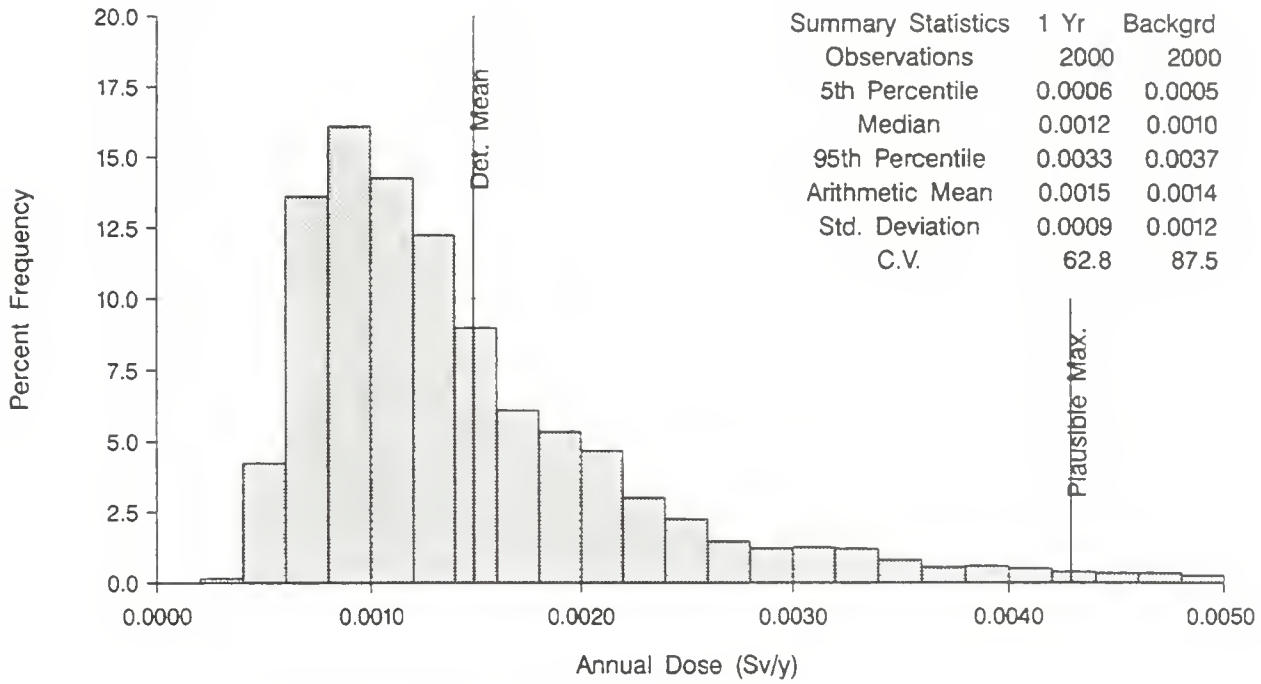
Table 4.2

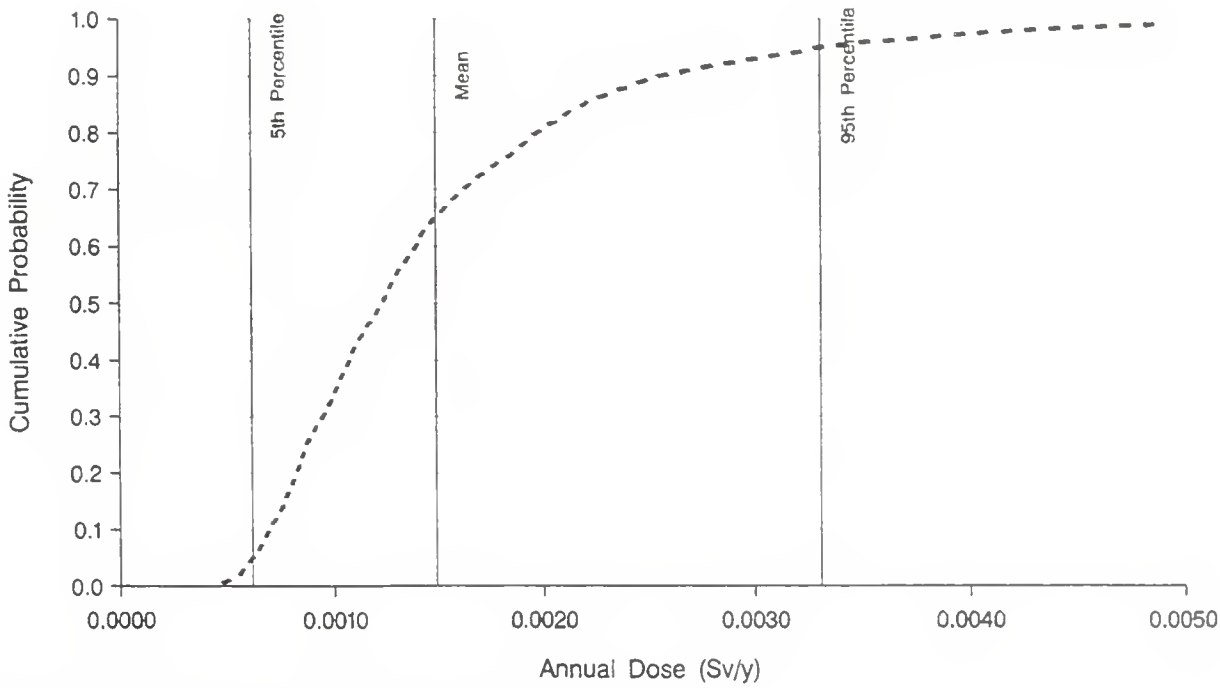
Probabilistic Estimates of Lifetime Risk

Location	Gamma Radiation Mean (% of Total)	Gamma Radiation 95th	Radon Mean (% of Total)	Radon 95th	Water Mean (% of Total)	Water 95th	Other Mean (% of Total)	Other 95th	Total Mean	Total 95th
All Deloro	1.1E-03 (17%)	1.5E-03	4.7E-03 (70%)	1.3E-02	7.4E-04 (11%)	1.6E-03	6.9E-05 (1%)	1.5E-04	6.6E-03	1.5E-02
Zone 1	1.1E-03 (12%)	1.4E-03	7.0E-03 (79%)	1.9E-02	7.4E-04 (8%)	1.6E-03	5.8E-05 (1%)	1.3E-04	8.8E-03	2.1E-02
Zone 2	1.1E-03 (19%)	1.3E-03	3.7E-03 (66%)	9.4E-03	7.3E-04 (13%)	1.5E-03	7.0E-05 (1%)	1.5E-04	5.5E-03	1.1E-02
Zone 3	1.2E-03 (20%)	1.5E-03	4.0E-03 (66%)	1.1E-02	7.5E-04 (13%)	1.6E-03	7.3E-05 (1%)	1.6E-04	6.0E-03	1.3E-02
Zone 4	1.3E-03 (9%)	1.5E-03	1.3E-02 (85%)	3.2E-02	7.4E-04 (5%)	1.6E-03	7.6E-05 (1%)	1.9E-04	1.5E-02	3.5E-02
Background	9.5E-04 (15%)	1.2E-03	4.4E-03 (71%)	1.5E-02	7.4E-04 (12%)	1.5E-03	1.0E-04 (2%)	1.7E-04	6.2E-03	1.6E-02

Figure 4.1

Distribution of Annual Dose for 1 Year Old in Deloro

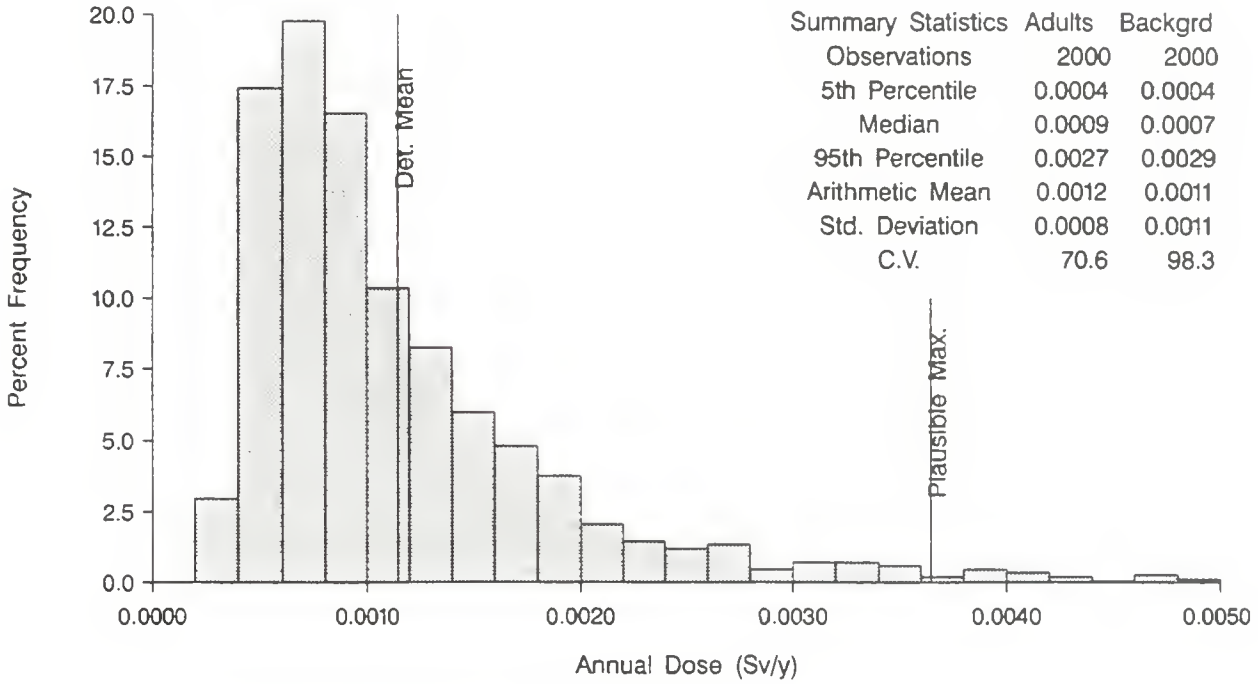


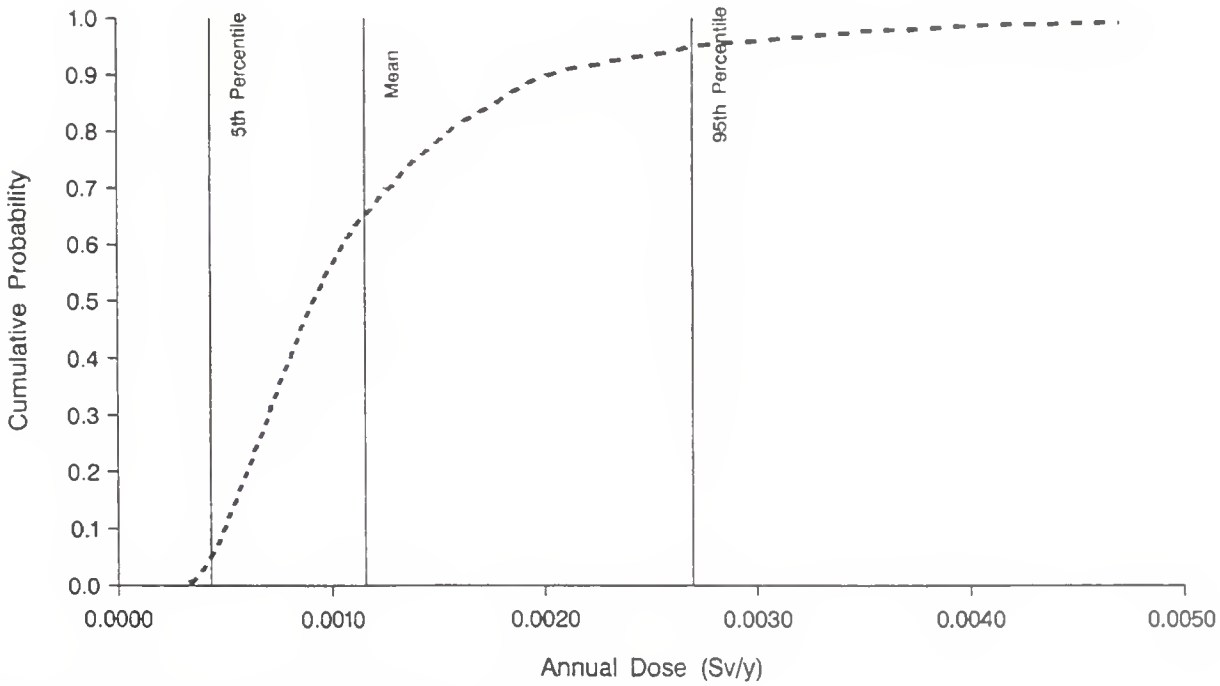


Horizontal axis was truncated at 99th percentile and 17 obs. were not shown.

Figure 4.2

Distribution of Annual Dose for Adults in Deloro

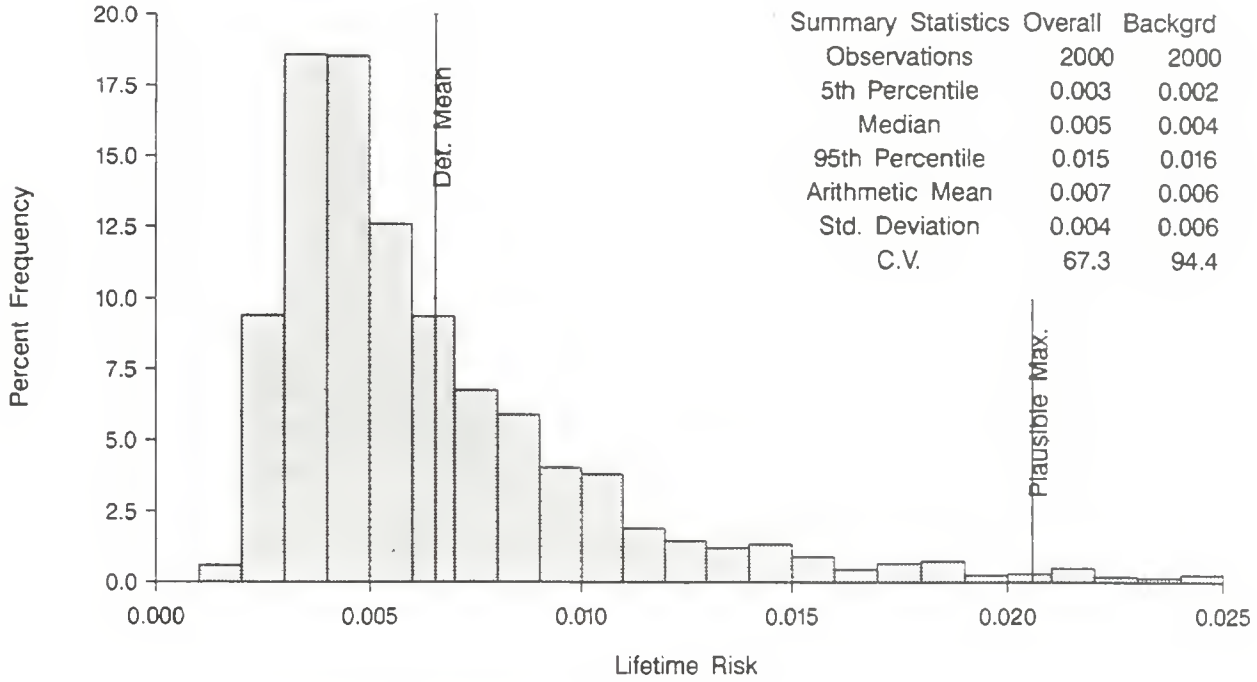


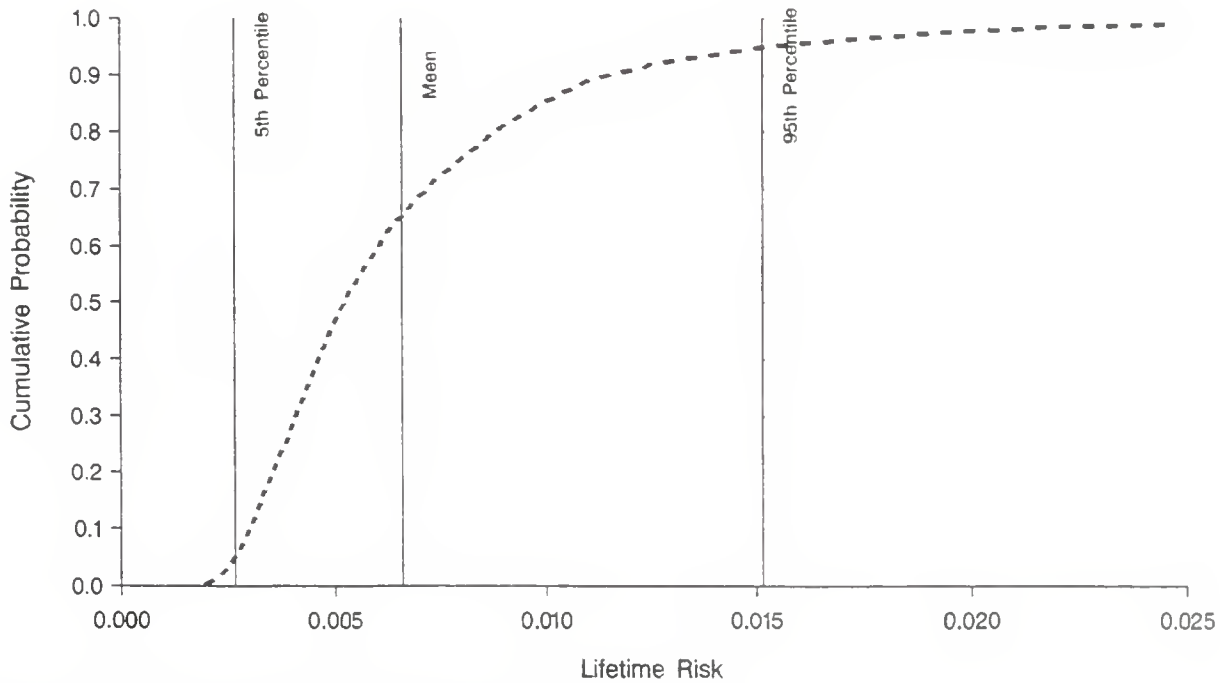


Horizontal axis was truncated at 99th percentile and 9 obs. were not shown.

Figure 4.3

Distribution of Lifetime Risk from Radiological Doses for All Deloro





Honzontal axis was truncated at 99th percentile and 15 obs. were not shown.

5.0 DISCUSSION AND CONTEXT FOR DOSE AND RISK ESTIMATES

Prior to discussing the estimates of risk and dose, it should be noted that the differences between the estimates for the Deloro and the background conditions are only approximate indicators of the incremental (above-background) impacts (if any) in Deloro. This is because the distributions used in this study to be representative of background conditions were taken from a wide variety of published sources and only approximate the background or baseline (i.e. unimpacted) levels that existed in Deloro before mining and any other industrial operations commenced. This was necessary to do because measurements of baseline conditions in Deloro do not exist. This is not an unusual occurrence in studies of historical situations.

It should also be noted that the "background" and other risk estimates include only those exposure pathways and exposure durations relevant to this study. Exposures to sources that would not be impacted by any conditions in Deloro (e.g. cosmic radiation, radioactivity in food other than home garden produce) were not included in any of the dose and risk estimates. In addition, exposures while away from Deloro were not included in the dose and risk estimates.

5.1 DELORO DOSES AND RISKS IN COMPARISON TO TYPICAL BACKGROUND LEVELS

The range of estimated lifetime risks from background radiation levels and from Deloro radiation levels are similar (Table 4.2). The mean lifetime risk estimate for Deloro conditions is 6.6×10^{-3} and the 95th percentile estimate is 1.5×10^{-2}. The mean lifetime Deloro risk level is slightly higher (by about 6%) compared to the background risk level while the estimate of the 95th percentile for Deloro radiation levels is slightly lower (by about 6%) than the 95th percentile value for background radiation levels. This indicates that the plausible range of lifetime risks in Deloro is within the range of risks from natural background radiation levels.

Notwithstanding the above, as previously noted there is some evidence of increased risk in Deloro due to radiation and/or radioactive contamination from the mine site. Risks from gamma radiation are highest nearest the mine site. For example, the mean lifetime risk estimate for gamma radiation for Zone 4 is 1.3×10^{-3} compared to 1.1×10^{-3} estimated for Zone 1. This is consistent with the 1 to 2 μR/h higher gamma radiation levels measured on Zone 4 properties compared to Zone 1.

Indoor radon measurements show the highest levels occurring in Zone 1 (farthest from the site) and in Zone 4 (nearest the site) so it is plausible that these concentrations are naturally occurring rather than attributable to radioactive contamination. The outdoor radon measurements in Deloro were highest, closest to the mine site; however this would only account for a small difference in the variations in indoor radon levels.

For other exposure pathways, estimated risks to Deloro residences attributable to uranium-series radionuclides are lower than the risks estimated for background levels. This is primarily due to the low soil concentrations measured in the town compared to the range of background levels. There

is, however, a possible trend in uranium soil concentrations where uranium levels are higher near the site than farther away. This suggests a potential incremental dose and risk due to Deloro contamination (but within typical background variations).

Relative to potential impacts of the former mine site, the differences in mean doses between Zone 4 (closest to the former mine site) and Zone 1 (farthest from the former mine site) are 0.5×10^{-4} Sv/y for gamma radiation and 0.5×10^{-5} Sv/y for other (non-radon) pathways (Table 4.1 for the 1 y old age group: doses for other ages are smaller). This is a combined difference of less than 0.06 mSv/y for these exposure pathways. This increment potentially due to contamination in Deloro is a small fraction of the 1 mSv/y dose limit (ICRP 1991) recommended for members of the public. As a further comparison, the differences between the mean estimates of the all Deloro and "background" total doses are less than 1 mSv/y for all age groups, with the exception of Zone 4 (likely due to normal variations in indoor radon levels).

5.2 Sensitivity Analysis and Major Dose Contributors

A sensitivity analysis was conducted to determine how much variation in the dose could be attributed to variation in input factors sampled during the probabilistic risk assessment. Two tests were done. The first, summarized in Table 5.1, shows for 20 combinations of zone (4 in Deloro) and age groups (5), the lowest and highest mean annual doses and the lowest and highest percentage contribution to dose. Gamma radiation accounts for 8.6% to 21% of the total dose and radon accounts for 60% to 87% of the total dose. Dose from water accounts for between 4% and 20% of the total (mean) dose. It should be emphasized that the water dose is the same for Deloro and background locations since the same concentrations were used. As previously noted, the doses from water are biased high as a consequence of the measured data being below reporting limits.

The second test was to assess the fraction of the total variability in dose explained by a particular variable. The results of the test are shown in Table 5.2. The results indicate:

- Predicted doses are most sensitive to the variability in indoor radon levels with typically 95% of the total dose explained by variations in the indoor radon level.

- The assumed variations in the Pb-210 and Po-210 drinking water concentrations were the next largest (but much less significant) contributors to the variations in total dose.

More detailed sensitivity analyses are provided in Appendix B.

5.3 Sources of Uncertainty in Dose and Risk Estimates

Radon

Uncertainty in the dose from radon most likely arises from two sources: first, is applying the indoor

radon concentrations measured during the Fall program to all seasons. Radon levels naturally vary from day-to-day and from season-to-season. The measurements were collected over a two-week period during the autumn and the seasonal averages, winter and summer, are likely within a factor or two of the measured values. The second source of uncertainty is the radon equilibrium factor used to convert radon levels to radon progeny levels (measured in working level months, WLM). A single value of 0.4 was used although radon equilibrium factors vary from home to home and from season-to-season with levels potentially ranging from about 0.25 to 0.8 (U.S. NCRP 1988).

The distribution of indoor radon levels in some zones, particularly in Zone 4 where three homes were sampled, are quite uncertain due to the relatively small number of homes in this zone. The uncertainty in radon dose in this zone is much higher than in Zones 2 and Zone 3 and the overall Deloro distribution. Uncertainty in the outdoor radon levels is less important than the uncertainty in indoor radon levels since outdoor levels are much lower than indoors and the time spent outdoors is much lower than the time spent indoors.

Uncertainty in the occupancy factors (time spent indoors or outdoors) has little effect on the overall uncertainty in risks from radon since the variation and uncertainty in these numbers is overwhelmed by the variability and uncertainty in radon concentrations and radon equilibrium fractions.

Based on the uncertainty in these factors, the estimated mean dose for the Village of Deloro from radon may be slightly conservative because the annual average radon concentrations are overestimated, and the 95th percentile of the mean dose for the Village may be slightly underestimated because the variability in radon in equilibrium factors was not included in the analysis. Estimated doses from Zone 4 are highly uncertain due to the limited number of homes used to determine the distribution of radon concentrations.

Gamma Radiation

Uncertainty in doses from gamma radiation exposures are relatively small compared to the uncertainties in doses from radon or uranium-series radionuclides. This is because gamma radiation levels are relatively precisely measured and the range of time spent indoors and outdoors has a limited range.

Uranium-Series Radionuclides

The major source of uncertainty in the estimated dose from the uranium-decay series arises from the water pathway. All radionuclide concentrations in water samples from the municipal supply, and with a few exceptions from the private wells, were reported as below the reporting limit. The sampling distributions for radionuclides in water reflect this uncertainty by being uniform from 0 to the reporting limit. There is no information on actual radionuclide concentrations in Deloro water other than that the levels are below a reporting limit. However, the doses from the water pathway based on this highly uncertain input distribution are substantially higher than the doses from the other

pathways (other than gamma radiation and radon) and dominate the total dose from the uranium-decay series.

Measured air concentrations can be variable from day-to-day and from season-to-season based on prevailing wind directions and condition of the soil (airborne dust levels are lower when the ground is covered by snow or wet). Dust concentrations for radionuclides other than Pb-210 or Po-210 were based on an assumed total suspended particulate (TSP) concentration and measured soil concentrations in soil. The seasonal air concentrations are relatively uncertain; however, the dose from these uncertain levels is very small compared to radon or gamma radiation doses in the Village.

Doses from garden produce and soil/dust consumption are based on measured soil concentrations that demonstrate relatively little variation from background. Uncertainty in biotransfer factors and indoor outdoor factors are present; however, since doses are small compared to radon and gamma radiation, and are below background estimates, the uncertainty in these doses is relatively unimportant .

Risk Factors

The risk estimates in this study implicitly assume the validity of the linear, no threshold (LNT) dose response model; that is, the risks of exposure to radiation are assumed to be directly proportional to the dose received, down to zero dose. There is much current debate on the LNT model, and on the appropriateness of estimating impacts from doses that are extremely small fractions of natural background doses. Some postulate the hormetic (i.e. beneficial) effects of low dose, low dose rate radiation. UNSCEAR (1994) has reported on the adaptive response of organisms, whereby small doses of radiation induce repair and/or stimulate proliferation, although there is no direct epidemiological evidence of adaptive response in humans.

A review of the biological effects of low doses of radiation by AECB's Advisory Committee on Radiological Protection (ACRP 1996) similarly notes that there is no direct proof that exposures, at least of adults, to 10 – 20 mSv per year for a few years causes any harmful effects on health. The ACRP then recommends that any detrimental harmful effects calculated using the LNT for radiation exposures of adults should be referred to as hypothetical health effects only.

The U.S. National Academy of Sciences (1990), in a comprehensive review of the health effects of exposure to low-level radiation, state that, at the dose and dose rates equivalent to those from natural background radiation (i.e. such as those in Deloro), the lower range of uncertainty in the risk estimates extends to zero.

Quantification of the magnitude of uncertainty in the risk estimates is beyond the scope of this study. However, the presence of a dose threshold for detrimental effects would render any impacts associated with the doses estimated in this study invalid and would overestimate the actual risks.

Lifetime Risk

Uncertainty in the distribution of lifetime risk from all radiological pathways comes primarily from two factors:

- uncertainty (and natural variability) in the distribution of indoor radon levels and indoor radon equilibrium levels; and

- to a much smaller degree, uncertainty in the radionuclide concentrations present in Deloro water.

There is also uncertainty in the ICRP (relative) risk projection model which formed the basis for the risk estimates in this study. Discussion of the magnitude of the uncertainty is beyond the scope of this study. However, the uncertainty affects equally both the background risks and risk estimates for the residents of Deloro.

5.4 POTENTIAL FOR RISK REDUCTION

The ALARA (as low as reasonably achievable) principal of radiation protection suggests that, even if doses and risks are already low, actions to reduce the risk further should be taken if the benefits of the actions (reduced risk) exceed the costs of such activities. No specific ALARA analysis has been done in this study but possible remedial actions that might be analyzed include the following.

Much of the potential incremental risk related to gamma radiation and possibly outdoor radon levels due to on-site materials. On-site reclamation plans include consolidation of these materials and placement of cover materials. This type of remedial action would reduce the potential incremental gamma radiation and radon related-risks from the site. For example, a 10 cm thick layer of compacted soil would reduce the gamma radiation levels by a factor of about 2 and a 20 cm cover would reduce gamma levels by a factor of about 4. To reduce radon flux by a factor of about 2 would require about a 1 m thick soil cover.

The observed soil concentration levels, and the gradient in uranium soil concentrations away from the mine site, are low compared to background levels. Clean-up of this material would not significantly reduce radiological risks to Deloro residents. The gamma radiation surveys indicate a few small elevated areas throughout the Village that may be attributable to radioactive slag or tailings intentionally moved from the mine site. Clean-up of these isolated pockets may reduce local gamma radiation exposures to some residents by 1 or 2 μR/h, but this would have only a very minor impact on overall values because of the localized nature of the exposures.

Some homes had radon levels approaching or exceeding 150 Bq/m^3; however, there is no basis to determine whether these levels are due to natural variation or show an effect of radiological contamination in the soil surrounding the home or within the home itself. Radon reduction techniques

are available to reduce radon levels in homes regardless of whether the radon levels are simply due to natural variation or have some component attributable to contamination.

The total risks and risks by exposure pathway estimated for the residents of Deloro are within the range of risks estimated from the variation in natural background radiation and radioactivity levels. On this basis, the people of Deloro do not appear to be exposed to unusual levels of radiological risk, and unusual actions to reduce these risks do not appear to be warranted from a health point on view.

Table 5.1

Summary of Contributions to Annual Mean Dose for Total Radiological Dose

Source	Lowest Mean Dose From Source (mSv)	Highest Mean Dose From Source (mSv)	Lowest Contribution to Total (%)	Highest Contribution to Total (%)
Gamma	0.16	1.35	8.6	21
Other	0.008	0.31	0.4	5.5
Radon	0.66	12.68	60	87
Water	0.11	1.02	4.0	20
Total	1.0375	3.5079		

Table 5.2

Summary of Variability Explained for Total Radiological Dose

Factor Type	Factor	Lowest Contribution to Variation (%)	Median Contribution to Variation (%)	Highest Contribution to Variation (%)
Media	radon indoors	89	95	99
Media	Pb-210 water	0.01	0.25	3.3
Media	Po-210 in water	<0.01	0.15	4.9

6.0 CONCLUSIONS

The Village of Deloro is adjacent to the site of a former gold mine and smelter. Although the mining ceased in the early 1900's, the smelter continued to operate into the 1950's processing ores from elsewhere in Ontario and from other countries. Some of the ores processed at the site contained high amounts of arsenic and other metals, while other ores contained elevated quantities of natural radioactivity, specifically the uranium decay series radionuclides. This study reports on the assessment of potential radiological risks to residents of Deloro. A parallel study assesses the potential risks from arsenic and other metals.

In considering the results of this analysis, it is important to remember that radioactivity and radiation is ubiquitous. Exposure to radiation and radioactivity is a part of our everyday life and is unavoidable. Thus, for exposure to radiation and radioactivity, comparison to natural background levels of radiation and radioactivity provides a useful context. The probabilistic risk assessment produced distributions of doses and risks for both Deloro-specific concentrations and for the range of natural background estimated for geologically similar areas in Ontario.

Based on the results of this study, the radiological doses and lifetime risks predicted for current residents of the Village of Deloro are comparable to and within the range of doses and risks for Ontario residents from natural background radioactivity.

On an annual basis, the estimated annual radiation dose to an adult living in Deloro, including both natural background for the area and the incremental contribution attributable to the mine site was estimated at about 1.2 millisieverts/year (mSv/y), as compared to 1.1 mSv/y estimated for typical background exposures. The corresponding maximum likely dose for the adult (maximum likely dose is taken as the 95th percentile) was about 2.9 mSv/y from natural background as compared to 2.7 mSv/y for a Deloro resident. The average dose to a one year old was estimated at about 1.5 mSv/y, as compared to 1.4 mSv/y estimated for natural background conditions. The corresponding maximum likely doses to a one year old were estimated at about 3.7 mSv/y from natural background conditions compared to about 3.3 mSv/y for a Deloro resident.

Estimates of lifetime risk from a lifetime of exposure were calculated for Deloro and natural background conditions. Since dose and risk are directly related, the estimated risks from radiation were similar for residents of Deloro and people exposed to natural background radiation. The mean value for lifetime risk from exposure to natural background was 6.2 per 1,000 and this is slightly lower than the typical Deloro conditions which were about 6.6 per 1,000 over a lifetime. The maximum likely lifetime radiological risk from natural background conditions was estimated to be about 1.6 per 100 and this value is slightly higher than the maximum likely risk, 1.5 per 100, estimated for Deloro conditions.

The risk to Deloro residents from periodic casual access to the former Deloro mine site was estimated to be less than about 5% of the mean risks estimated for the average Deloro resident.

The major contributor to lifetime risk was radon which accounted for about 70% of the average lifetime risk for Deloro conditions. Gamma radiation and water ingestion accounted for about 17% and 11% of the mean lifetime risk, respectively. The estimated risk from water ingestion is highly uncertain, and in all likelihood, an overestimate since the risk is driven by the laboratory reporting limits. (The water concentrations were below the reporting limit; however the concentrations were assumed to range up to the reporting limit for the risk assessment.) The drinking water pathway assumes the same uncertainty for all zones including natural background and, therefore, the doses from this pathway are identical for the Deloro resident and a person exposed to natural background conditions. Risk from inhalation of airborne dust and ingestion of soil, dust, and home garden produce accounted for only 1% of the total lifetime risk.

A sensitivity analysis indicated that the lifetime risk estimates were most sensitive to variability in the indoor radon concentrations. The variability in indoor radon concentrations explained more than 95% of the overall variability in the lifetime risk. Typically, the variation explained by each of the other input factors was less than 1%.

Estimates of the mean annual doses to adults from natural background and also from present conditions in Deloro are shown in the Table below. The Table also shows the upper 95th percentile estimate of the total annual doses. The ratio of the 95th percentile annual dose, which is an estimate of the maximum annual dose that anyone is likely to receive, to the mean annual dose average is between about 2 to 3.

Although the estimated doses and consequent risks for residents of the Village overall are comparable to the range of those from natural background, there is an indication that there is a gradient in dose and risk from gamma radiation, with dose and risk decreasing with increasing distance from the former Deloro mine site. The major contributor to the potential gradient is the relative elevation in gamma radiation levels close to the mine site that are attributable to radiation contamination on the mine site. It is possible that some gamma radiation may arise from contaminated materials located off-site. The distribution of natural mineralization may also be a factor in the observed gradient.

Location	Mean Total Dose (mSv/y)	Mean Gamma Radiation Dose (mSv/y)	Mean Radon Dose (mSv/y)	95th percentile of total dose (mSv/y)
Background	1.1	0.16	0.81	2.9
Deloro Village	1.2	0.20	0.85	2.7
Zone 1 (furthest from the mine site)	1.6	0.18	1.3	3.8
Zone 2	0.97	0.18	0.67	2.1
Zone 3	1.0	0.20	0.72	2.2
Zone 4 (nearest to the mine site)	2.7	0.23	2.3	6.3

With respect to radon, elevated outdoor radon levels were observed near the site fence and therefore, for the area closest to the mine site, there is a possibility of some small elevation in the radon levels that could be attributed to site contamination. Radon doses are dominated by indoor levels and radon doses were highest in the nearest and furthest zones from the site. It must be emphasized that natural background levels of radon are highly variable and would naturally vary widely from home to home even in the absence of radioactive contamination.

Although residents of Deloro do not appear to be exposed to levels of radiation and radioactivity above those from the typical range of background, there is a suggestion that close to the mine site the radiation levels may be elevated relative to those further away from the mine site. Thus, consistent with the radiation protection principle that doses from radiation should be as kept as low as reasonably achievable, social and economic factors taken into account (ALARA), some consideration should be given to practical measures to reduce radiation risks.

Gamma radiation levels can be readily reduced through shielding and distance. Thus, contaminated materials at the perimeter of the site (and in off-site pockets) could be moved away from the perimeter which would reduce off-site gamma levels. In addition, gamma radiation levels are attenuated by covering with soil or other natural materials. Consolidation and cover of on-site radioactive materials would reduce gamma radiation exposures to Deloro residents.

With respect to radon, the outdoor radon levels appear to be elevated close to the mine site relative to the assumed levels of natural background. Radon is also attenuated by soil cover, although not nearly so effectively as it is for gamma radiation. Further investigation would be required to evaluate with confidence whether the elevated outdoor radon levels near the site are in fact a reflection of normal variation or rather the result of radioactive contamination.

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APPENDIX A:

INTRODUCTION TO RADIATION AND RADIOACTIVITY

APPENDIX A: INTRODUCTION TO NATURAL RADIATION AND RADIOACTIVITY

Because of the novel nature of the subject of this study, a brief introduction to some radiological terms is presented below to assist those unfamiliar with the concepts of radiation and radioactivity.

We have always been subjected to natural radiation. We are exposed to radiation from the sun and outer space. Naturally occurring radioactive materials are present in the earth, the houses we live in and the buildings where we work, and the food and drink we consume. There are radioactive aerosols and gases in the air we breathe and even our own bodies contain naturally occurring radioactive elements. The level of this inescapable natural "background" radiation exposure varies greatly from place to place.

We are also exposed to sources of radiation that we ourselves create. X-rays and other kinds of radiation used for medical purposes, fall-out from past nuclear weapons tests and the small quantities of radioactive materials which are allowed to escape to the environment in the course of normal operation of nuclear installations are some examples.

There are basically three types of radiation that are emitted from the naturally occurring radioactivity present in all rocks and soils: alpha, beta and gamma radiation. Alpha radiation is a particle that is readily stopped in air or by a sheet of paper. Beta radiation is a smaller particle (an electron) that travels further in air but is also readily stopped by 1-2 cm of water or by the near-surface of the body. Gamma radiation is a form of electromagnetic radiation, such as light or radiowaves, but of greater energy and is more penetrating than either alpha or beta radiation. For these reasons, alpha and beta radiation are of most concern when they are taken into the body by inhalation or ingestion, while gamma radiation can also be a hazard when outside the body.

Uranium is a naturally occurring radioactive element that is widely distributed on earth. Natural uranium consists of uranium-238 and uranium-234 in the U-238 series and uranium-235, which leads another radioactive decay serves. (The latter, because of its low abundance, is not usually considered radiologically significant (Lowe 1997), although it can be under some conditions.) Through the radioactive decay of uranium-238 (with the emission of alpha, beta and gamma radiation), a series of different radionuclides is formed until stable, non-radioactive lead-206 is reached (see Figure A.1). Unless disturbed by chemical separation or other means, all the radionuclides in the U-238 decay series are in radioactive equilibrium; that is, each gram of uranium-bearing material contains equal radioactivities of each radionuclide in the decay series equal to the concentration of U-238.

One important member of the decay series is radon-222, which is a gas and the decay product of radon-226. It is chemically inert (non-reactive) and when it is produced near the surface of material containing radium-226, it is free to diffuse and enter the atmosphere. Since all soils contain some uranium and radium, our atmosphere and our homes all contain radon. In fact, most of the exposure we receive from background radiation is caused by indoor radon and its decay products. Because

of normal atmospheric dispersion, radon exposures outdoors are usually not an issue in terms of radiological dose.

What are the units used for radiation and radioactivity? The S.I. (Systeme International de Unités) unit of radioactivity, is the becquerel (Bq) and equals 1 nuclear disintegration per second. The concentration of natural uranium in "typical" rocks and soils is about 1 to 10 ppm, or about 0.01 to 0.1 Bq g^{-1} each of U-238 and its decay products since 1 ppm of natural uranium corresponds to 0.0123 Bq/g of U-238.

For gamma radiation, the most common historical unit of exposure is the roentgen (R). Typical background exposure rates are in the order of 3 to 10 μR (microroentgen or 10^{-6} R) per hour but are highly variable from location to location. The S.I. unit of dose is the sievert (Sv) or millisievert (mSv, 10^{-3} Sv). The potential risks of exposure to radiation are considered to be proportional to the dose measured in Sv. Natural background radiation results in a dose of about 2 mSv per year (including about 1 mSv y^{-1} from radon progeny), although some places in the world experience exposure rates five or more times higher i.e. more than 10 mSv per year.

Exposure to radon progeny is often measured in terms of a special historical unit, the working level month (WLM), where 1 WLM is the exposure to 1 working level (WL) of radon progeny for 170 hours (defined as a working month). The WL is a measure of the concentration of radon progeny in air and is equivalent to a concentration of approximately 3700 Bq/m^3 of radon in radioactive equilibrium with its progeny. The degree of equilibrium between radon and its progeny depends on a number of parameters, including the age or residence time of the air. Typical indoor equilibrium values are in the order of 0.4 (U.S. NCRP 1987), with the result that 3700 Bq/m^3 of radon in indoor air would be equivalent to 0.4 WL. Typical indoor radon levels (highly valuable but about 50 Bq/m^3) result in annual exposures of about 0.2 WLM or a dose rate of about 0.8 mSv/y, using a dose conversion factor of 4 mSv per WLM for members of the public (ICRP 1993).

Outdoor radon concentrations (typically in the range of about 5 to 20 Bq/m^3) are generally much lower than indoor concentrations and depend on the amount of radon exhaled by soil and the atmospheric factors controlling its dispersion.

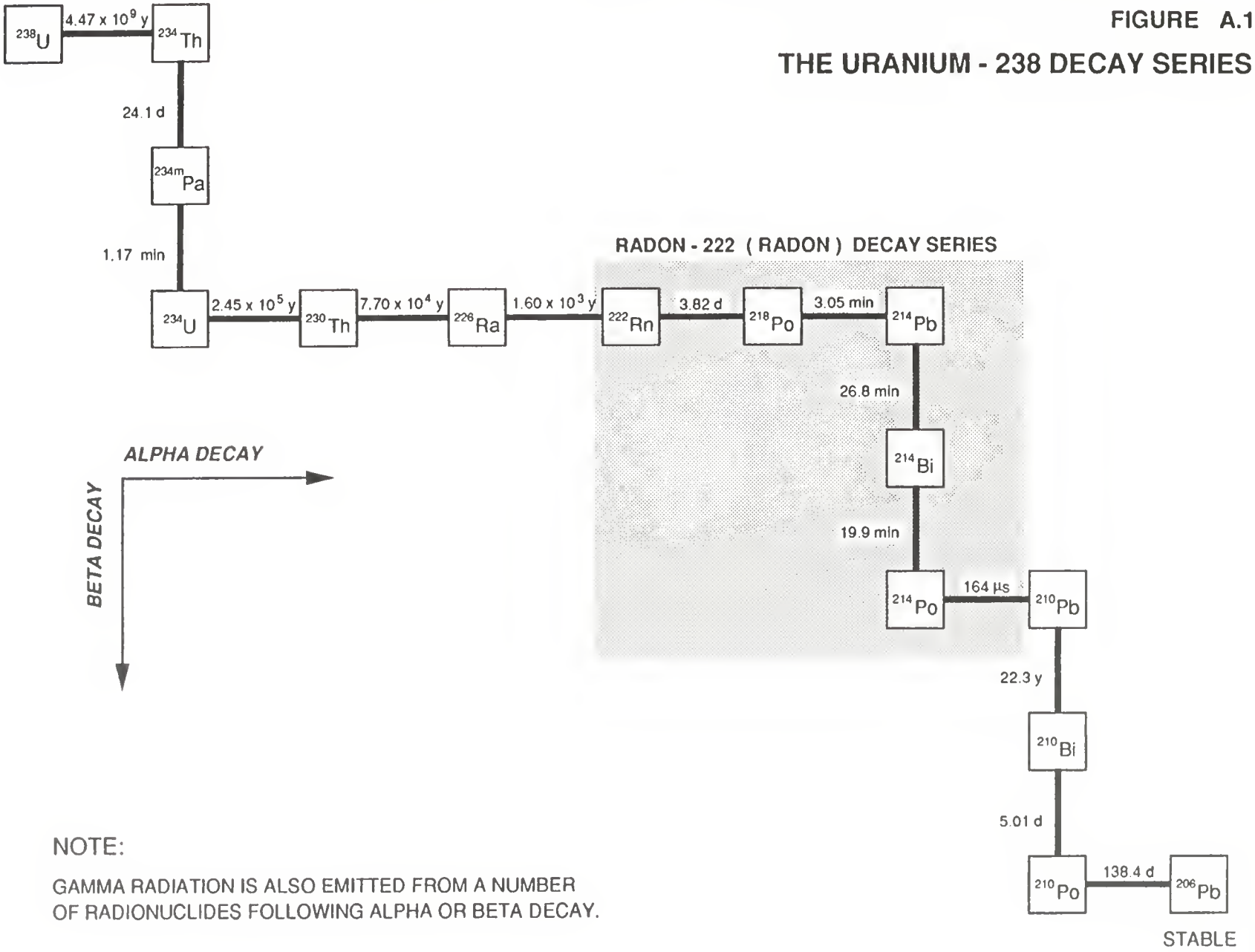
For radiation protection purposes, the risk of exposure to radiation is assumed to be proportional to the effective radiation dose measured in mSv down to zero dose. This is known as the linear, no threshold (LNT) dose response model. There is much current debate on the LNT model, and on the appropriateness of estimating impacts from doses that are fractions of natural background doses. Some even postulate the hormetic (i.e. beneficial) effects of low dose, low dose rate radiation. A review of the biological effects of low doses of radiation by AECB's Advisory Committee on Radiological Protection (ACRP 1996) notes that there is no direct proof that exposures, at least of adults, to 10 to 20 mSv per year for a few years causes any harmful effects on health. The ACRP then recommends that any detrimental harmful effects calculated using the LNT for radiation exposures of adults should be referred to as hypothetical health effects only.

The U.S. National Academy of Sciences (1990), in a comprehensive review of the health effects of exposure to low-level radiation, state that, at the dose and dose rates equivalent to those from natural background radiation, the lower range of uncertainty in the risk estimates extends to zero.

Assuming the validity of the LNT model, how large is the risk of exposure to low levels of radiation? According to the International Commission on Radiological Protection (ICRP), the risk of cancer to workers is 48 per million per mSv, comprising 40 fatal cancer and 8 non-fatal cancer per million per mSv. For members of the public who have a different age distribution, the risk is 60 per million per mSv (50 fatal and 10 non-fatal) averaged over all ages. This means that if 1 million people were each exposed to an additional 1 mSv/y of radiation (or about one-half of the annual background dose) for 50 years, about 2500 excess cancer deaths would be predicted by the LNT model. These would be in addition to the approximately 250,000 persons per million who will die of cancer from all other causes. The excess deaths due to irradiation of 1 million people with 1 mSv/y each could not be statistically detected due to the normal variations in cancer deaths in the general population.

FIGURE A.1

THE URANIUM - 238 DECAY SERIES



NOTE:

GAMMA RADIATION IS ALSO EMITTED FROM A NUMBER OF RADIONUCLIDES FOLLOWING ALPHA OR BETA DECAY.

APPENDIX B

DETAILED DOSE AND RISK ESTIMATES

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B.2.28 Distribution of Annual Dose (Sv/y) for 10 Year Old from All Radiological Sources in Zone 4
B.2.29 Distribution of Annual Dose (Sv/y) for 15 Year Old from All Radiological Sources in Zone 4
B.2.30 Distribution of Annual Dose (Sv/y) for Adult from All Radiological Sources in Zone 4
B.2.31 Distribution of Lifetime Risk for All Age Groups from All Radiological Sources in Deloro
B.2.32 Distribution of Lifetime Risk for All Age Groups from All Radiological Sources in Background
B.2.33 Distribution of Lifetime Risk for All Age Groups from All Radiological Sources in Zone 1
B.2.34 Distribution of Lifetime Risk for All Age Groups from All Radiological Sources in Zone 2
B.2.35 Distribution of Lifetime Risk for All Age Groups from All Radiological Sources in Zone 3
B.2.36 Distribution of Lifetime Risk for All Age Groups from All Radiological Sources in Zone 4
B.2.37 Distribution of Lifetime Risk for All Age Groups from Radon in Deloro
B.2.38 Distribution of Lifetime Risk for All Age Groups from Radon in Background
B.2.39 Distribution of Lifetime Risk for All Age Groups from Gamma in Deloro
B.2.40 Distribution of Lifetime Risk for All Age Groups from Gamma in Background
B.2.41 Distribution of Lifetime Risk for All Age Groups from Other Sources in Deloro
B.2.42 Distribution of Lifetime Risk for All Age Groups from Other Sources in Background

APPENDIX B: DETAILED DOSE AND RISK ESTIMATES

This appendix contains tables with detailed summaries of the radiological dose and risk assessments, figures showing the distributions of the results from the probabilistic analysis, and detailed sensitivity analyses. Summaries from this appendix and some individual figures are discussed in the main text.

B.1 STATISTICS ON DOSE AND RISK ESTIMATES AND COMPARISON TO BACKGROUND

Tables B.1.1 to B.1.4 contain the summary results for each scenario assessed in the deterministic (Tables B.1.1 , B.1.2) and probabilistic (Tables B.1.3 to B.1.4) analyses by the source of dose (i.e. radon, gamma radiation, water or other), by age group, and by the zone considered. The mean and plausible maximum doses are presented for the deterministic analyses, and the mean and 95th percentile doses or risks are provided for the probabilistic analyses. The tables also provide comparisons to background conditions (reported in brackets as ratio of zone/background) and show the ratios of the plausible maximum to the mean for the deterministic analyses, and of the 95th percentile to the mean for the probabilistic analyses.

B.2 GRAPHICAL PRESENTATION OF PROBABILISTIC DOSE AND RISK ESTIMATES

Figures B.2.1 to B.2.42 show the distributions of annual doses and lifetime risks from the probabilistic analyses. A few of these figures are presented in the main report. The dose figures (Figures B.2.1 to B.2.30) show the 30 combinations of six "zones" (all of Deloro, background and Zones 1 to 4) and five age groups (1 y, 5 y, 10 y, 15 y and adult). The first set of risk figures (Figures B.2.31 to B.2.36) show lifetime risks from all radiological sources for the six zones. The second set of risk figures (Figure B.2.37 to B.2.42) show lifetime risks from each of the three major sources (radon, gamma and other) in each of two zones (all Deloro and background).

Each figure shows both a histogram and the cumulative density function (CDF) of the dose and risk results for the assessment. The histogram appears in the upper half of the figure and contains annotations with the mean and plausible maximum values from the deterministic analyses. Summary statistics from the probabilistic assessment for the all Deloro zone and for background conditions are shown in the upper portion of the figure to provide a comparison of the distribution of Deloro doses with background doses.

The lower half of each figure shows the CDF. The CDF is annotated with the locations of the 5th percentile, mean and 95th percentile of the distribution.

B.3 SENSITIVITY ANALYSES

Quantitative sensitivity analyses were conducted to determine the most important contributions to total dose (or lifetime risk) and how much of the variation in dose (or lifetime risk) is explained by the variability in the input factors. These analyses were conducted for the distribution of doses

received for all combinations of age group and zone in Deloro.

The dose tables B.3.1 to B.3.30 show the contributions to annual dose for the 30 combinations of the six zones and five age groups. The first set of risk tables (Tables B.3.31 to B.3.36) show the contributions to lifetime risk from all sources in each of the six zones. The second set of risk tables (Tables B.3.37 to B.3.42) show the factors affecting lifetime risks for each of the three major dose contributors (radon, gamma radiation, and others) in each of two zones (all of Deloro and background).

Summaries from these analyses are presented in the main body of the report for doses received from the combination of radon, gamma, water and other sources of radiological dose. Sensitivity analyses have also been run for each source (e.g. radon or gamma or water or other) by itself.

In each sensitivity analysis, the total dose (or lifetime risk) and the doses (or lifetime risk) by separate sources (e.g. gamma, radon, water, other) were summarized. This identifies the source that contributes most to the dose (or lifetime risk) for that age group and zone.

A regression model (PROC GLM in SAS version 6.12) was fit to determine how much variation in the risk assessment output, the annual dose (or lifetime risk), was explained by the variability in the input factors. (The SAS System is a widely used, integrated system of software from the SAS Institute Inc. that provides control over data access, management, analysis and presentation.) The variation, sum-of-squares, explained by the input factor was compared to the total variation, again sum-of-squares, in the estimated doses. The ratio of variability explained by the input factor to the total variation in the dose or risk was expressed as a percentage. A high percentage means that a high proportion of the variation in the dose (or lifetime risk) was explained by that factor.

Each table contains two parts: the first part provides summary statistics on the input factors; and the second part reports the sensitivity analysis results with the input factors ordered with the factors explaining most of the variation (i.e. highest variability explained in %) located at the top of the table. The factors were classified into the following types: media concentration, consumption rate, occupancy factor and transfer factors. The tables also summarize the input factors according to the variability of the input expressed in relative percent terms by the coefficient of variation (CV), and report the 5^{th} and 95^{th} percentiles of the sampled value.

Table B.1.1
Deterministic Analyses:
Annual Dose (Mean and Plausible Maximum)
As a Function of Zone and Age

Zone	Analyte	Medium	Mean (Sv/y) (ratio to bkgd.)	Plausible Maximum (Sv/y) (ratio to bkgd.)	Ratio of Plausible Max. to Mean
1 year old					
Background	All	Total	1.4E-03 (1.0)	4.7E-03 (1.0)	3.3
	Gamma	GammaRad	2.4E-04 (1.0)	3.1E-04 (1.0)	1.3
	Other	Air	2.3E-05 (1.0)	9.5E-05 (1.0)	4.1
	Other	Fruit	2.5E-06 (1.0)	8.5E-05 (1.0)	33.7
	Other	OtherVeg	7.2E-07 (1.0)	2.9E-05 (1.0)	39.7
	Other	RootVeg	1.1E-06 (1.0)	4.0E-05 (1.0)	35.3
	Other	SoilDust	4.6E-06 (1.0)	5.0E-05 (1.0)	10.7
	Other	Water	2.2E-04 (1.0)	9.8E-04 (1.0)	4.5
	Radon	Radon	9.5E-04 (1.0)	3.1E-03 (1.0)	3.3
All Deloro	All	Total	1.5E-03 (1.0)	4.3E-03 (0.9)	2.9
	Gamma	GammaRad	2.8E-04 (1.2)	3.7E-04 (1.2)	1.3
	Other	Air	1.8E-05 (0.8)	9.6E-05 (1.0)	5.3
	Other	Fruit	1.8E-06 (0.7)	4.8E-05 (0.6)	27.3
	Other	OtherVeg	5.1E-07 (0.7)	1.6E-05 (0.6)	32.2
	Other	RootVeg	8.0E-07 (0.7)	2.3E-05 (0.6)	28.6
	Other	SoilDust	3.2E-06 (0.7)	2.7E-05 (0.5)	8.2
	Other	Water	2.2E-04 (1.0)	9.8E-04 (1.0)	4.5
	Radon	Radon	9.7E-04 (1.0)	2.7E-03 (0.9)	2.8
Zone 1	All	Total	1.9E-03 (1.4)	5.6E-03 (1.2)	2.9
	Gamma	GammaRad	2.7E-04 (1.1)	3.5E-04 (1.1)	1.3
	Other	Air	1.4E-05 (0.6)	7.9E-05 (0.8)	5.5
	Other	Fruit	1.7E-06 (0.7)	5.3E-05 (0.6)	32.1
	Other	OtherVeg	4.8E-07 (0.7)	1.8E-05 (0.6)	37.8
	Other	RootVeg	7.5E-07 (0.7)	2.5E-05 (0.6)	33.5
	Other	SoilDust	3.0E-06 (0.7)	2.9E-05 (0.6)	9.6
	Other	Water	2.2E-04 (1.0)	9.8E-04 (1.0)	4.5
	Radon	Radon	1.4E-03 (1.5)	4.0E-03 (1.3)	2.8
Zone 2	All	Total	1.3E-03 (0.9)	3.5E-03 (0.7)	2.7
	Gamma	GammaRad	2.6E-04 (1.1)	3.2E-04 (1.0)	1.2
	Other	Air	1.7E-05 (0.7)	9.4E-05 (1.0)	5.4
	Other	Fruit	1.9E-06 (0.7)	5.0E-05 (0.6)	26.7
	Other	OtherVeg	5.4E-07 (0.7)	1.7E-05 (0.6)	31.4
	Other	RootVeg	8.4E-07 (0.7)	2.3E-05 (0.6)	27.9
	Other	SoilDust	3.4E-06 (0.7)	2.7E-05 (0.6)	8
	Other	Water	2.2E-04 (1.0)	9.8E-04 (1.0)	4.5
	Radon	Radon	7.7E-04 (0.8)	1.9E-03 (0.6)	2.5
Zone 3	All	Total	1.4E-03 (1.0)	3.9E-03 (0.8)	2.8
	Gamma	GammaRad	2.9E-04 (1.2)	3.8E-04 (1.2)	1.3
	Other	Air	1.9E-05 (0.8)	1.0E-04 (1.1)	5.4
	Other	Fruit	1.9E-06 (0.7)	5.0E-05 (0.6)	26.7
	Other	OtherVeg	5.4E-07 (0.7)	1.7E-05 (0.6)	31.5
	Other	RootVeg	8.4E-07 (0.7)	2.4E-05 (0.6)	27.9
	Other	SoilDust	3.4E-06 (0.7)	2.7E-05 (0.6)	8
	Other	Water	2.2E-04 (1.0)	9.8E-04 (1.0)	4.5
	Radon	Radon	8.5E-04 (0.9)	2.3E-03 (0.7)	2.7
Zone 4	All	Total	3.3E-03 (2.3)	8.8E-03 (1.9)	2.6
	Gamma	GammaRad	3.3E-04 (1.4)	3.7E-04 (1.2)	1.1
	Other	Air	2.0E-05 (0.8)	1.1E-04 (1.2)	5.8
	Other	Fruit	1.7E-06 (0.7)	5.0E-05 (0.6)	30.2
	Other	OtherVeg	4.8E-07 (0.7)	1.7E-05 (0.6)	35.5
	Other	RootVeg	7.5E-07 (0.7)	2.4E-05 (0.6)	31.5
	Other	SoilDust	3.1E-06 (0.7)	2.8E-05 (0.6)	9.1
	Other	Water	2.2E-04 (1.0)	9.8E-04 (1.0)	4.5
	Radon	Radon	2.7E-03 (2.9)	7.2E-03 (2.3)	2.6

Table B.1.1
Deterministic Analyses:
Annual Dose (Mean and Plausible Maximum)
As a Function of Zone and Age

Zone	Analyte	Medium	Mean (Sv/y) (ratio to bkgd.)	Plausible Maximum (Sv/y) (ratio to bkgd.)	Ratio of Plausible Max. to Mean
5 year old					
Background	All	Total	1.3E-03 (1.0)	4.5E-03 (1.0)	3.5
	Gamma	GammaRad	2.1E-04 (1.0)	3.2E-04 (1.0)	1.5
	Other	Air	2.1E-05 (1.0)	9.1E-05 (1.0)	4.4
	Other	Fruit	1.8E-06 (1.0)	6.5E-05 (1.0)	36.5
	Other	OtherVeg	6.5E-07 (1.0)	2.7E-05 (1.0)	41.1
	Other	RootVeg	1.1E-06 (1.0)	3.9E-05 (1.0)	36.9
	Other	SoilDust	2.4E-06 (1.0)	3.2E-05 (1.0)	13.2
	Other	Water	1.8E-04 (1.0)	6.9E-04 (1.0)	3.9
	Radon	Radon	8.8E-04 (1.0)	3.2E-03 (1.0)	3.7
All Deloro	All	Total	1.3E-03 (1.0)	4.1E-03 (0.9)	3.1
	Gamma	GammaRad	2.5E-04 (1.2)	3.8E-04 (1.2)	1.5
	Other	Air	1.6E-05 (0.8)	9.2E-05 (1.0)	5.7
	Other	Fruit	1.2E-06 (0.7)	3.6E-05 (0.6)	28.8
	Other	OtherVeg	4.6E-07 (0.7)	1.5E-05 (0.6)	32.5
	Other	RootVeg	7.5E-07 (0.7)	2.2E-05 (0.6)	29.2
	Other	SoilDust	1.7E-06 (0.7)	1.6E-05 (0.5)	9.4
	Other	Water	1.8E-04 (1.0)	6.9E-04 (1.0)	3.9
	Radon	Radon	8.9E-04 (1.0)	2.9E-03 (0.9)	3.2
Zone 1	All	Total	1.8E-03 (1.4)	5.4E-03 (1.2)	3.1
	Gamma	GammaRad	2.4E-04 (1.1)	3.6E-04 (1.1)	1.5
	Other	Air	1.3E-05 (0.6)	7.5E-05 (0.8)	5.8
	Other	Fruit	1.2E-06 (0.7)	4.0E-05 (0.6)	33.8
	Other	OtherVeg	4.3E-07 (0.7)	1.6E-05 (0.6)	38
	Other	RootVeg	7.0E-07 (0.7)	2.4E-05 (0.6)	34.2
	Other	SoilDust	1.6E-06 (0.7)	1.7E-05 (0.5)	11.1
	Other	Water	1.8E-04 (1.0)	6.9E-04 (1.0)	3.9
	Radon	Radon	1.3E-03 (1.5)	4.2E-03 (1.3)	3.2
Zone 2	All	Total	1.1E-03 (0.9)	3.2E-03 (0.7)	2.8
	Gamma	GammaRad	2.3E-04 (1.1)	3.3E-04 (1.0)	1.4
	Other	Air	1.6E-05 (0.7)	8.9E-05 (1.0)	5.7
	Other	Fruit	1.3E-06 (0.7)	3.7E-05 (0.6)	28.1
	Other	OtherVeg	4.8E-07 (0.7)	1.5E-05 (0.6)	31.7
	Other	RootVeg	7.9E-07 (0.7)	2.3E-05 (0.6)	28.5
	Other	SoilDust	1.8E-06 (0.7)	1.6E-05 (0.5)	9.2
	Other	Water	1.8E-04 (1.0)	6.9E-04 (1.0)	3.9
	Radon	Radon	7.1E-04 (0.8)	2.0E-03 (0.6)	2.9
Zone 3	All	Total	1.2E-03 (1.0)	3.6E-03 (0.8)	2.9
	Gamma	GammaRad	2.6E-04 (1.2)	3.9E-04 (1.2)	1.5
	Other	Air	1.7E-05 (0.8)	9.6E-05 (1.0)	5.7
	Other	Fruit	1.3E-06 (0.7)	3.7E-05 (0.6)	28.2
	Other	OtherVeg	4.8E-07 (0.7)	1.5E-05 (0.6)	31.7
	Other	RootVeg	7.9E-07 (0.7)	2.3E-05 (0.6)	28.5
	Other	SoilDust	1.8E-06 (0.7)	1.6E-05 (0.5)	9.2
	Other	Water	1.8E-04 (1.0)	6.9E-04 (1.0)	3.9
	Radon	Radon	7.8E-04 (0.9)	2.4E-03 (0.7)	3
Zone 4	All	Total	3.0E-03 (2.3)	8.8E-03 (1.9)	2.9
	Gamma	GammaRad	3.0E-04 (1.4)	3.8E-04 (1.2)	1.3
	Other	Air	1.8E-05 (0.8)	1.1E-04 (1.2)	6.1
	Other	Fruit	1.2E-06 (0.7)	3.7E-05 (0.6)	31.8
	Other	OtherVeg	4.3E-07 (0.7)	1.5E-05 (0.6)	35.8
	Other	RootVeg	7.1E-07 (0.7)	2.3E-05 (0.6)	32.2
	Other	SoilDust	1.6E-06 (0.7)	1.6E-05 (0.5)	10.4
	Other	Water	1.8E-04 (1.0)	6.9E-04 (1.0)	3.9
	Radon	Radon	2.5E-03 (2.9)	7.5E-03 (2.3)	3

Table B.1.1
Deterministic Analyses:
Annual Dose (Mean and Plausible Maximum)
As a Function of Zone and Age

Zone	Analyte	Medium	Mean (Sv/y) (ratio to bkgd.)	Plausible Maximum (Sv/y) (ratio to bkgd.)	Ratio of Plausible Max. to Mean
10 year old					
Background	All	Total	1.2E-03 (1.0)	4.3E-03 (1.0)	3.5
	Gamma	GammaRad	1.9E-04 (1.0)	2.9E-04 (1.0)	1.5
	Other	Air	1.4E-05 (1.0)	6.0E-05 (1.0)	4.3
	Other	Fruit	1.6E-06 (1.0)	5.8E-05 (1.0)	35.7
	Other	OtherVeg	5.9E-07 (1.0)	2.4E-05 (1.0)	40.2
	Other	RootVeg	9.7E-07 (1.0)	3.5E-05 (1.0)	36.2
	Other	SoilDust	1.8E-06 (1.0)	2.5E-05 (1.0)	13.9
	Other	Water	1.5E-04 (1.0)	6.0E-04 (1.0)	3.9
	Radon	Radon	8.8E-04 (1.0)	3.2E-03 (1.0)	3.7
All Deloro	All	Total	1.3E-03 (1.0)	3.9E-03 (0.9)	3.1
	Gamma	GammaRad	2.3E-04 (1.2)	3.5E-04 (1.2)	1.5
	Other	Air	1.1E-05 (0.8)	6.0E-05 (1.0)	5.7
	Other	Fruit	1.1E-06 (0.7)	3.3E-05 (0.6)	28.8
	Other	OtherVeg	4.1E-07 (0.7)	1.3E-05 (0.6)	32.5
	Other	RootVeg	6.8E-07 (0.7)	2.0E-05 (0.6)	29.2
	Other	SoilDust	1.2E-06 (0.7)	1.2E-05 (0.5)	9.4
	Other	Water	1.5E-04 (1.0)	6.0E-04 (1.0)	3.9
	Radon	Radon	8.9E-04 (1.0)	2.9E-03 (0.9)	3.2
Zone 1	All	Total	1.7E-03 (1.4)	5.3E-03 (1.2)	3.1
	Gamma	GammaRad	2.1E-04 (1.1)	3.3E-04 (1.1)	1.5
	Other	Air	8.5E-06 (0.6)	4.9E-05 (0.8)	5.8
	Other	Fruit	1.1E-06 (0.7)	3.6E-05 (0.6)	33.8
	Other	OtherVeg	3.9E-07 (0.7)	1.5E-05 (0.6)	38.1
	Other	RootVeg	6.4E-07 (0.7)	2.2E-05 (0.6)	34.2
	Other	SoilDust	1.2E-06 (0.7)	1.3E-05 (0.5)	11
	Other	Water	1.5E-04 (1.0)	6.0E-04 (1.0)	3.9
	Radon	Radon	1.3E-03 (1.5)	4.2E-03 (1.3)	3.2
Zone 2	All	Total	1.1E-03 (0.9)	3.1E-03 (0.7)	2.8
	Gamma	GammaRad	2.1E-04 (1.1)	3.0E-04 (1.0)	1.4
	Other	Air	1.0E-05 (0.7)	5.8E-05 (1.0)	5.7
	Other	Fruit	1.2E-06 (0.7)	3.4E-05 (0.6)	28.1
	Other	OtherVeg	4.4E-07 (0.7)	1.4E-05 (0.6)	31.7
	Other	RootVeg	7.2E-07 (0.7)	2.0E-05 (0.6)	28.5
	Other	SoilDust	1.3E-06 (0.7)	1.2E-05 (0.5)	9.2
	Other	Water	1.5E-04 (1.0)	6.0E-04 (1.0)	3.9
	Radon	Radon	7.1E-04 (0.8)	2.0E-03 (0.6)	2.9
Zone 3	All	Total	1.2E-03 (1.0)	3.5E-03 (0.8)	2.9
	Gamma	GammaRad	2.4E-04 (1.2)	3.6E-04 (1.2)	1.5
	Other	Air	1.1E-05 (0.8)	6.3E-05 (1.1)	5.7
	Other	Fruit	1.2E-06 (0.7)	3.4E-05 (0.6)	28.2
	Other	OtherVeg	4.4E-07 (0.7)	1.4E-05 (0.6)	31.7
	Other	RootVeg	7.2E-07 (0.7)	2.1E-05 (0.6)	28.5
	Other	SoilDust	1.3E-06 (0.7)	1.2E-05 (0.5)	9.2
	Other	Water	1.5E-04 (1.0)	6.0E-04 (1.0)	3.9
	Radon	Radon	7.8E-04 (0.9)	2.4E-03 (0.7)	3
Zone 4	All	Total	3.0E-03 (2.4)	8.6E-03 (2.0)	2.9
	Gamma	GammaRad	2.7E-04 (1.4)	3.5E-04 (1.2)	1.3
	Other	Air	1.2E-05 (0.8)	7.0E-05 (1.2)	6.1
	Other	Fruit	1.1E-06 (0.7)	3.4E-05 (0.6)	31.8
	Other	OtherVeg	3.9E-07 (0.7)	1.4E-05 (0.6)	35.8
	Other	RootVeg	6.4E-07 (0.7)	2.1E-05 (0.6)	32.2
	Other	SoilDust	1.2E-06 (0.7)	1.2E-05 (0.5)	10.4
	Other	Water	1.5E-04 (1.0)	6.0E-04 (1.0)	3.9
	Radon	Radon	2.5E-03 (2.9)	7.5E-03 (2.3)	3

Table B.1.1
Deterministic Analyses:
Annual Dose (Mean and Plausible Maximum)
As a Function of Zone and Age

Zone	Analyte	Medium	Mean (Sv/y) (ratio to bkgd.)	Plausible Maximum (Sv/y) (ratio to bkgd.)	Ratio of Plausible Max. to Mean
15 year old					
Background	All	Total	1.2E-03 (1.0)	4.5E-03 (1.0)	3.7
	Gamma	GammaRad	1.7E-04 (1.0)	2.7E-04 (1.0)	1.6
	Other	Air	1.2E-05 (1.0)	7.7E-05 (1.0)	6.6
	Other	Fruit	1.9E-06 (1.0)	6.5E-05 (1.0)	34.7
	Other	OtherVeg	8.8E-07 (1.0)	3.4E-05 (1.0)	38.4
	Other	RootVeg	1.7E-06 (1.0)	5.3E-05 (1.0)	32
	Other	SoilDust	1.2E-06 (1.0)	8.5E-06 (1.0)	7.3
	Other	Water	2.0E-04 (1.0)	8.7E-04 (1.0)	4.3
	Radon	Radon	8.1E-04 (1.0)	3.1E-03 (1.0)	3.8
All Deloro	All	Total	1.2E-03 (1.0)	4.1E-03 (0.9)	3.3
	Gamma	GammaRad	2.0E-04 (1.2)	3.2E-04 (1.2)	1.6
	Other	Air	8.9E-06 (0.8)	5.4E-05 (0.7)	6.1
	Other	Fruit	1.3E-06 (0.7)	3.9E-05 (0.6)	29.5
	Other	OtherVeg	6.2E-07 (0.7)	2.0E-05 (0.6)	32.6
	Other	RootVeg	1.2E-06 (0.7)	3.2E-05 (0.6)	27.2
	Other	SoilDust	8.1E-07 (0.7)	3.9E-06 (0.5)	4.9
	Other	Water	2.0E-04 (1.0)	8.7E-04 (1.0)	4.3
	Radon	Radon	8.2E-04 (1.0)	2.7E-03 (0.9)	3.3
Zone 1	All	Total	1.6E-03 (1.4)	5.3E-03 (1.2)	3.3
	Gamma	GammaRad	1.9E-04 (1.1)	3.0E-04 (1.1)	1.6
	Other	Air	7.1E-06 (0.6)	4.5E-05 (0.6)	6.3
	Other	Fruit	1.2E-06 (0.7)	4.3E-05 (0.7)	34.5
	Other	OtherVeg	5.8E-07 (0.7)	2.2E-05 (0.7)	38.2
	Other	RootVeg	1.1E-06 (0.7)	3.5E-05 (0.7)	31.9
	Other	SoilDust	7.6E-07 (0.7)	4.3E-06 (0.5)	5.7
	Other	Water	2.0E-04 (1.0)	8.7E-04 (1.0)	4.3
	Radon	Radon	1.2E-03 (1.5)	4.0E-03 (1.3)	3.3
Zone 2	All	Total	1.1E-03 (0.9)	3.2E-03 (0.7)	3.1
	Gamma	GammaRad	1.9E-04 (1.1)	2.8E-04 (1.0)	1.5
	Other	Air	8.6E-06 (0.7)	5.3E-05 (0.7)	6.2
	Other	Fruit	1.4E-06 (0.7)	4.0E-05 (0.6)	28.8
	Other	OtherVeg	6.5E-07 (0.7)	2.1E-05 (0.6)	31.8
	Other	RootVeg	1.2E-06 (0.7)	3.3E-05 (0.6)	26.6
	Other	SoilDust	8.6E-07 (0.7)	4.0E-06 (0.5)	4.7
	Other	Water	2.0E-04 (1.0)	8.7E-04 (1.0)	4.3
	Radon	Radon	6.5E-04 (0.8)	2.0E-03 (0.6)	3
Zone 3	All	Total	1.1E-03 (1.0)	3.6E-03 (0.8)	3.2
	Gamma	GammaRad	2.1E-04 (1.2)	3.3E-04 (1.2)	1.6
	Other	Air	9.2E-06 (0.8)	5.7E-05 (0.7)	6.2
	Other	Fruit	1.4E-06 (0.7)	4.0E-05 (0.6)	28.8
	Other	OtherVeg	6.5E-07 (0.7)	2.1E-05 (0.6)	31.8
	Other	RootVeg	1.2E-06 (0.7)	3.3E-05 (0.6)	26.6
	Other	SoilDust	8.6E-07 (0.7)	4.1E-06 (0.5)	4.7
	Other	Water	2.0E-04 (1.0)	8.7E-04 (1.0)	4.3
	Radon	Radon	7.2E-04 (0.9)	2.3E-03 (0.7)	3.2
Zone 4	All	Total	2.8E-03 (2.3)	8.6E-03 (1.9)	3.1
	Gamma	GammaRad	2.4E-04 (1.4)	3.2E-04 (1.2)	1.3
	Other	Air	9.7E-06 (0.8)	6.4E-05 (0.8)	6.6
	Other	Fruit	1.3E-06 (0.7)	4.1E-05 (0.6)	32.5
	Other	OtherVeg	5.8E-07 (0.7)	2.1E-05 (0.6)	35.9
	Other	RootVeg	1.1E-06 (0.7)	3.3E-05 (0.6)	30
	Other	SoilDust	7.6E-07 (0.7)	4.1E-06 (0.5)	5.4
	Other	Water	2.0E-04 (1.0)	8.7E-04 (1.0)	4.3
	Radon	Radon	2.3E-03 (2.9)	7.2E-03 (2.3)	3.1

Table B.1.1
Deterministic Analyses:
Annual Dose (Mean and Plausible Maximum)
As a Function of Zone and Age

Zone	Analyte	Medium	Mean (Sv/y) (ratio to bkgd.)	Plausible Maximum (Sv/y) (ratio to bkgd.)	Ratio of Plausible Max. to Mean
Adult					
Background	All	Total	1.1E-03 (1.0)	4.0E-03 (1.0)	3.6
	Gamma	GammaRad	1.6E-04 (1.0)	2.5E-04 (1.0)	1.6
	Other	Air	1.1E-05 (1.0)	5.1E-05 (1.0)	4.7
	Other	Fruit	6.2E-07 (1.0)	2.5E-05 (1.0)	40.2
	Other	OtherVeg	3.5E-07 (1.0)	1.5E-05 (1.0)	43
	Other	RootVeg	4.7E-07 (1.0)	1.9E-05 (1.0)	39.7
	Other	SoilDust	5.3E-07 (1.0)	4.6E-06 (1.0)	8.7
	Other	Water	1.1E-04 (1.0)	4.3E-04 (1.0)	4
	Radon	Radon	8.3E-04 (1.0)	3.2E-03 (1.0)	3.9
All Deloro	All	Total	1.1E-03 (1.0)	3.6E-03 (0.9)	3.2
	Gamma	GammaRad	2.0E-04 (1.2)	3.1E-04 (1.2)	1.6
	Other	Air	8.3E-06 (0.8)	5.1E-05 (1.0)	6.1
	Other	Fruit	4.3E-07 (0.7)	1.2E-05 (0.5)	27.9
	Other	OtherVeg	2.4E-07 (0.7)	7.2E-06 (0.5)	29.8
	Other	RootVeg	3.3E-07 (0.7)	9.1E-06 (0.5)	27.5
	Other	SoilDust	3.6E-07 (0.7)	1.8E-06 (0.4)	4.9
	Other	Water	1.1E-04 (1.0)	4.3E-04 (1.0)	4
	Radon	Radon	8.4E-04 (1.0)	2.8E-03 (0.9)	3.4
Zone 1	All	Total	1.5E-03 (1.4)	5.0E-03 (1.2)	3.2
	Gamma	GammaRad	1.8E-04 (1.1)	2.9E-04 (1.1)	1.6
	Other	Air	6.7E-06 (0.6)	4.2E-05 (0.8)	6.3
	Other	Fruit	4.0E-07 (0.7)	1.3E-05 (0.5)	32.7
	Other	OtherVeg	2.3E-07 (0.7)	7.9E-06 (0.5)	34.9
	Other	RootVeg	3.1E-07 (0.7)	1.0E-05 (0.5)	32.2
	Other	SoilDust	3.4E-07 (0.6)	2.0E-06 (0.4)	5.7
	Other	Water	1.1E-04 (1.0)	4.3E-04 (1.0)	4
	Radon	Radon	1.3E-03 (1.5)	4.2E-03 (1.3)	3.3
Zone 2	All	Total	9.6E-04 (0.9)	2.8E-03 (0.7)	2.9
	Gamma	GammaRad	1.8E-04 (1.1)	2.6E-04 (1.0)	1.5
	Other	Air	8.1E-06 (0.7)	5.0E-05 (1.0)	6.1
	Other	Fruit	4.5E-07 (0.7)	1.2E-05 (0.5)	27.2
	Other	OtherVeg	2.5E-07 (0.7)	7.4E-06 (0.5)	29.1
	Other	RootVeg	3.5E-07 (0.7)	9.4E-06 (0.5)	26.8
	Other	SoilDust	3.8E-07 (0.7)	1.8E-06 (0.4)	4.8
	Other	Water	1.1E-04 (1.0)	4.3E-04 (1.0)	4
	Radon	Radon	6.7E-04 (0.8)	2.0E-03 (0.6)	3
Zone 3	All	Total	1.1E-03 (1.0)	3.2E-03 (0.8)	3
	Gamma	GammaRad	2.0E-04 (1.2)	3.2E-04 (1.3)	1.6
	Other	Air	8.7E-06 (0.8)	5.3E-05 (1.0)	6.1
	Other	Fruit	4.6E-07 (0.7)	1.2E-05 (0.5)	27.2
	Other	OtherVeg	2.5E-07 (0.7)	7.4E-06 (0.5)	29.1
	Other	RootVeg	3.5E-07 (0.7)	9.4E-06 (0.5)	26.9
	Other	SoilDust	3.8E-07 (0.7)	1.8E-06 (0.4)	4.8
	Other	Water	1.1E-04 (1.0)	4.3E-04 (1.0)	4
	Radon	Radon	7.4E-04 (0.9)	2.4E-03 (0.7)	3.2
Zone 4	All	Total	2.7E-03 (2.5)	8.3E-03 (2.1)	3.1
	Gamma	GammaRad	2.3E-04 (1.4)	3.0E-04 (1.2)	1.3
	Other	Air	9.1E-06 (0.8)	6.0E-05 (1.2)	6.6
	Other	Fruit	4.1E-07 (0.7)	1.3E-05 (0.5)	30.8
	Other	OtherVeg	2.3E-07 (0.7)	7.5E-06 (0.5)	32.9
	Other	RootVeg	3.1E-07 (0.7)	9.5E-06 (0.5)	30.4
	Other	SoilDust	3.4E-07 (0.7)	1.9E-06 (0.4)	5.4
	Other	Water	1.1E-04 (1.0)	4.3E-04 (1.0)	4
	Radon	Radon	2.4E-03 (2.9)	7.5E-03 (2.3)	3.2

Table B.1.2
Deterministic Analyses:
Lifetime Risk (Mean and Plausible Maximum)
As a Function of Zone

Zone	Analyte	Medium	Mean (ratio to bkgd.)	Plausible Maximum (ratio to bkgd.)	Ratio of Plausible Max. to Mean
Background	All	Total	6.3E-03 (1.0)	2.3E-02 (1.0)	3.6
	Gamma	GammaRad	9.5E-04 (1.0)	1.5E-03 (1.0)	1.5
	Other	Air	7.3E-05 (1.0)	3.4E-04 (1.0)	4.7
	Other	Fruit	6.1E-06 (1.0)	2.2E-04 (1.0)	36.9
	Other	OtherVeg	2.6E-06 (1.0)	1.1E-04 (1.0)	41.2
	Other	RootVeg	4.1E-06 (1.0)	1.5E-04 (1.0)	36.7
	Other	SoilDust	6.8E-06 (1.0)	7.5E-05 (1.0)	11.1
	Other	Water	7.4E-04 (1.0)	3.0E-03 (1.0)	4.1
	Radon	Radon	4.6E-03 (1.0)	1.7E-02 (1.0)	3.8
All Deloro	All	Total	6.6E-03 (1.0)	2.1E-02 (0.9)	3.1
	Gamma	GammaRad	1.1E-03 (1.2)	1.8E-03 (1.2)	1.5
	Other	Air	5.6E-05 (0.8)	3.3E-04 (1.0)	5.9
	Other	Fruit	4.3E-06 (0.7)	1.2E-04 (0.5)	28.4
	Other	OtherVeg	1.8E-06 (0.7)	5.8E-05 (0.5)	31.4
	Other	RootVeg	2.9E-06 (0.7)	8.1E-05 (0.5)	28.1
	Other	SoilDust	4.7E-06 (0.7)	3.6E-05 (0.5)	7.6
	Other	Water	7.4E-04 (1.0)	3.0E-03 (1.0)	4.1
	Radon	Radon	4.6E-03 (1.0)	1.5E-02 (0.9)	3.3
Zone 1	All	Total	8.7E-03 (1.4)	2.8E-02 (1.2)	3.2
	Gamma	GammaRad	1.1E-03 (1.1)	1.7E-03 (1.1)	1.5
	Other	Air	4.5E-05 (0.6)	2.7E-04 (0.8)	6
	Other	Fruit	4.0E-06 (0.7)	1.3E-04 (0.6)	33.3
	Other	OtherVeg	1.7E-06 (0.7)	6.4E-05 (0.6)	36.8
	Other	RootVeg	2.7E-06 (0.7)	8.9E-05 (0.6)	33
	Other	SoilDust	4.4E-06 (0.7)	4.0E-05 (0.5)	9
	Other	Water	7.4E-04 (1.0)	3.0E-03 (1.0)	4.1
	Radon	Radon	6.9E-03 (1.5)	2.2E-02 (1.3)	3.3
Zone 2	All	Total	5.5E-03 (0.9)	1.6E-02 (0.7)	2.9
	Gamma	GammaRad	1.1E-03 (1.1)	1.5E-03 (1.0)	1.4
	Other	Air	5.5E-05 (0.7)	3.2E-04 (0.9)	5.9
	Other	Fruit	4.5E-06 (0.7)	1.2E-04 (0.6)	27.7
	Other	OtherVeg	1.9E-06 (0.7)	6.0E-05 (0.5)	30.6
	Other	RootVeg	3.0E-06 (0.7)	8.4E-05 (0.6)	27.4
	Other	SoilDust	5.0E-06 (0.7)	3.7E-05 (0.5)	7.5
	Other	Water	7.4E-04 (1.0)	3.0E-03 (1.0)	4.1
	Radon	Radon	3.7E-03 (0.8)	1.1E-02 (0.6)	2.9
Zone 3	All	Total	6.0E-03 (1.0)	1.8E-02 (0.8)	3
	Gamma	GammaRad	1.2E-03 (1.2)	1.8E-03 (1.2)	1.5
	Other	Air	5.8E-05 (0.8)	3.5E-04 (1.0)	5.9
	Other	Fruit	4.5E-06 (0.7)	1.3E-04 (0.6)	27.7
	Other	OtherVeg	1.9E-06 (0.7)	6.0E-05 (0.5)	30.6
	Other	RootVeg	3.0E-06 (0.7)	8.4E-05 (0.6)	27.5
	Other	SoilDust	5.0E-06 (0.7)	3.7E-05 (0.5)	7.5
	Other	Water	7.4E-04 (1.0)	3.0E-03 (1.0)	4.1
	Radon	Radon	4.0E-03 (0.9)	1.3E-02 (0.7)	3.1
Zone 4	All	Total	1.5E-02 (2.4)	4.5E-02 (2.0)	3
	Gamma	GammaRad	1.3E-03 (1.4)	1.7E-03 (1.2)	1.3
	Other	Air	6.1E-05 (0.8)	3.9E-04 (1.1)	6.3
	Other	Fruit	4.0E-06 (0.7)	1.3E-04 (0.6)	31.3
	Other	OtherVeg	1.7E-06 (0.7)	6.0E-05 (0.6)	34.6
	Other	RootVeg	2.7E-06 (0.7)	8.4E-05 (0.6)	31
	Other	SoilDust	4.4E-06 (0.7)	3.7E-05 (0.5)	8.4
	Other	Water	7.4E-04 (1.0)	3.0E-03 (1.0)	4.1
	Radon	Radon	1.3E-02 (2.9)	4.0E-02 (2.3)	3.1

Table B.1.3
Probabilistic Analyses:
Annual Dose (Mean and 95th Percentile)
As a Function of Zone and Age

Zone	Analyte	Medium	Mean (Sv/y) (ratio to bkgd.)	95th Percentile (Sv/y) (ratio to bkgd.)	Ratio of 95th Percentile to Mean
1 year old					
Background	All	Total	1.4E-03 (1.0)	3.7E-03 (1.0)	2.6
	Gamma	GammaRad	2.3E-04 (1.0)	2.9E-04 (1.0)	1.2
	Other	Air	2.4E-05 (1.0)	4.7E-05 (1.0)	1.9
	Other	Fruit	2.9E-06 (1.0)	1.1E-05 (1.0)	3.7
	Other	OtherVeg	7.9E-07 (1.0)	3.0E-06 (1.0)	3.8
	Other	RootVeg	1.3E-06 (1.0)	5.1E-06 (1.0)	3.8
	Other	SoilDust	5.3E-06 (1.0)	1.9E-05 (1.0)	3.6
	Other	Water	2.2E-04 (1.0)	5.9E-04 (1.0)	2.7
	Radon	Radon	9.3E-04 (1.0)	3.0E-03 (1.0)	3.3
All Deloro	All	Total	1.5E-03 (1.1)	3.3E-03 (0.9)	2.2
	Gamma	GammaRad	2.8E-04 (1.2)	3.6E-04 (1.3)	1.3
	Other	Air	1.8E-05 (0.7)	4.2E-05 (0.9)	2.4
	Other	Fruit	1.8E-06 (0.6)	6.1E-06 (0.6)	3.4
	Other	OtherVeg	4.8E-07 (0.6)	1.9E-06 (0.6)	4
	Other	RootVeg	8.2E-07 (0.6)	2.9E-06 (0.6)	3.5
	Other	SoilDust	3.2E-06 (0.6)	1.1E-05 (0.6)	3.5
	Other	Water	2.1E-04 (1.0)	5.6E-04 (1.0)	2.7
	Radon	Radon	9.7E-04 (1.1)	2.8E-03 (0.9)	2.9
Zone 1	All	Total	2.0E-03 (1.4)	4.5E-03 (1.2)	2.3
	Gamma	GammaRad	2.7E-04 (1.1)	3.5E-04 (1.2)	1.3
	Other	Air	1.5E-05 (0.6)	3.8E-05 (0.8)	2.6
	Other	Fruit	1.6E-06 (0.6)	6.4E-06 (0.6)	3.9
	Other	OtherVeg	4.7E-07 (0.6)	1.7E-06 (0.6)	3.5
	Other	RootVeg	7.7E-07 (0.6)	2.9E-06 (0.6)	3.8
	Other	SoilDust	3.1E-06 (0.6)	1.1E-05 (0.6)	3.7
	Other	Water	2.2E-04 (1.0)	5.9E-04 (1.0)	2.7
	Radon	Radon	1.5E-03 (1.6)	4.1E-03 (1.4)	2.8
Zone 2	All	Total	1.3E-03 (0.9)	2.5E-03 (0.7)	1.9
	Gamma	GammaRad	2.6E-04 (1.1)	3.1E-04 (1.1)	1.2
	Other	Air	1.8E-05 (0.7)	4.5E-05 (1.0)	2.5
	Other	Fruit	1.9E-06 (0.6)	6.7E-06 (0.6)	3.5
	Other	OtherVeg	5.2E-07 (0.7)	2.1E-06 (0.7)	4
	Other	RootVeg	8.7E-07 (0.7)	3.2E-06 (0.6)	3.7
	Other	SoilDust	3.5E-06 (0.7)	1.2E-05 (0.6)	3.5
	Other	Water	2.2E-04 (1.0)	5.8E-04 (1.0)	2.7
	Radon	Radon	7.7E-04 (0.8)	2.0E-03 (0.7)	2.6
Zone 3	All	Total	1.4E-03 (1.0)	2.8E-03 (0.8)	2
	Gamma	GammaRad	2.9E-04 (1.2)	3.7E-04 (1.3)	1.3
	Other	Air	1.9E-05 (0.8)	4.8E-05 (1.0)	2.6
	Other	Fruit	1.9E-06 (0.7)	7.3E-06 (0.7)	3.8
	Other	OtherVeg	5.3E-07 (0.7)	2.1E-06 (0.7)	4.1
	Other	RootVeg	8.5E-07 (0.6)	3.1E-06 (0.6)	3.7
	Other	SoilDust	3.4E-06 (0.6)	1.3E-05 (0.7)	3.7
	Other	Water	2.2E-04 (1.0)	5.7E-04 (1.0)	2.6
	Radon	Radon	8.3E-04 (0.9)	2.2E-03 (0.7)	2.7
Zone 4	All	Total	3.2E-03 (2.3)	7.4E-03 (2.0)	2.3
	Gamma	GammaRad	3.3E-04 (1.4)	3.6E-04 (1.2)	1.1
	Other	Air	2.0E-05 (0.8)	5.3E-05 (1.1)	2.6
	Other	Fruit	1.8E-06 (0.6)	6.1E-06 (0.6)	3.5
	Other	OtherVeg	4.7E-07 (0.6)	1.8E-06 (0.6)	3.9
	Other	RootVeg	7.8E-07 (0.6)	2.9E-06 (0.6)	3.7
	Other	SoilDust	3.1E-06 (0.6)	1.1E-05 (0.6)	3.5
	Other	Water	2.2E-04 (1.0)	6.0E-04 (1.0)	2.8
	Radon	Radon	2.7E-03 (2.9)	6.7E-03 (2.2)	2.5

Table B.1.3
Probabilistic Analyses:
Annual Dose (Mean and 95th Percentile)
As a Function of Zone and Age

Zone	Analyte	Medium	Mean (Sv/y) (ratio to bkgd.)	95th Percentile (Sv/y) (ratio to bkgd.)	Ratio of 95th Percentile to Mean
5 year old					
Background	All	Total	1.3E-03 (1.0)	3.2E-03 (1.0)	2.5
	Gamma	GammaRad	2.1E-04 (1.0)	2.6E-04 (1.0)	1.3
	Other	Air	2.2E-05 (1.0)	4.1E-05 (1.0)	1.9
	Other	Fruit	2.2E-06 (1.0)	7.7E-06 (1.0)	3.5
	Other	OtherVeg	7.1E-07 (1.0)	2.6E-06 (1.0)	3.6
	Other	RootVeg	1.2E-06 (1.0)	4.2E-06 (1.0)	3.5
	Other	SoilDust	2.7E-06 (1.0)	9.1E-06 (1.0)	3.3
	Other	Water	1.8E-04 (1.0)	4.3E-04 (1.0)	2.5
	Radon	Radon	8.6E-04 (1.0)	2.8E-03 (1.0)	3.3
All Deloro	All	Total	1.3E-03 (1.1)	3.1E-03 (1.0)	2.3
	Gamma	GammaRad	2.5E-04 (1.2)	3.3E-04 (1.3)	1.3
	Other	Air	1.6E-05 (0.7)	4.1E-05 (1.0)	2.6
	Other	Fruit	1.3E-06 (0.6)	4.5E-06 (0.6)	3.5
	Other	OtherVeg	4.4E-07 (0.6)	1.7E-06 (0.7)	3.8
	Other	RootVeg	7.2E-07 (0.6)	2.6E-06 (0.6)	3.7
	Other	SoilDust	1.6E-06 (0.6)	5.4E-06 (0.6)	3.4
	Other	Water	1.7E-04 (1.0)	4.2E-04 (1.0)	2.4
	Radon	Radon	9.0E-04 (1.0)	2.6E-03 (0.9)	2.9
Zone 1	All	Total	1.8E-03 (1.4)	4.1E-03 (1.3)	2.3
	Gamma	GammaRad	2.4E-04 (1.1)	3.1E-04 (1.2)	1.3
	Other	Air	1.3E-05 (0.6)	3.3E-05 (0.8)	2.6
	Other	Fruit	1.3E-06 (0.6)	4.4E-06 (0.6)	3.5
	Other	OtherVeg	4.0E-07 (0.6)	1.7E-06 (0.6)	4.1
	Other	RootVeg	7.0E-07 (0.6)	2.4E-06 (0.6)	3.5
	Other	SoilDust	1.5E-06 (0.6)	5.1E-06 (0.6)	3.4
	Other	Water	1.8E-04 (1.0)	4.5E-04 (1.0)	2.5
	Radon	Radon	1.3E-03 (1.6)	3.7E-03 (1.3)	2.8
Zone 2	All	Total	1.1E-03 (0.9)	2.2E-03 (0.7)	2
	Gamma	GammaRad	2.3E-04 (1.1)	2.8E-04 (1.1)	1.2
	Other	Air	1.6E-05 (0.7)	4.1E-05 (1.0)	2.5
	Other	Fruit	1.4E-06 (0.6)	4.9E-06 (0.6)	3.6
	Other	OtherVeg	4.7E-07 (0.7)	1.7E-06 (0.7)	3.7
	Other	RootVeg	7.7E-07 (0.6)	2.8E-06 (0.7)	3.6
	Other	SoilDust	1.7E-06 (0.6)	5.9E-06 (0.6)	3.4
	Other	Water	1.7E-04 (1.0)	4.3E-04 (1.0)	2.5
	Radon	Radon	7.1E-04 (0.8)	1.8E-03 (0.6)	2.5
Zone 3	All	Total	1.2E-03 (1.0)	2.6E-03 (0.8)	2.1
	Gamma	GammaRad	2.6E-04 (1.2)	3.4E-04 (1.3)	1.3
	Other	Air	1.7E-05 (0.8)	4.3E-05 (1.1)	2.6
	Other	Fruit	1.4E-06 (0.6)	4.9E-06 (0.6)	3.5
	Other	OtherVeg	4.7E-07 (0.7)	1.9E-06 (0.7)	4
	Other	RootVeg	7.7E-07 (0.6)	2.8E-06 (0.7)	3.6
	Other	SoilDust	1.7E-06 (0.6)	5.8E-06 (0.6)	3.5
	Other	Water	1.8E-04 (1.0)	4.2E-04 (1.0)	2.4
	Radon	Radon	7.7E-04 (0.9)	2.1E-03 (0.7)	2.7
Zone 4	All	Total	2.9E-03 (2.3)	6.7E-03 (2.1)	2.3
	Gamma	GammaRad	3.0E-04 (1.4)	3.3E-04 (1.3)	1.1
	Other	Air	1.8E-05 (0.8)	5.0E-05 (1.2)	2.8
	Other	Fruit	1.3E-06 (0.6)	4.6E-06 (0.6)	3.6
	Other	OtherVeg	4.4E-07 (0.6)	1.7E-06 (0.6)	3.8
	Other	RootVeg	7.1E-07 (0.6)	2.4E-06 (0.6)	3.3
	Other	SoilDust	1.6E-06 (0.6)	5.3E-06 (0.6)	3.4
	Other	Water	1.7E-04 (1.0)	4.2E-04 (1.0)	2.4
	Radon	Radon	2.4E-03 (2.8)	6.2E-03 (2.2)	2.5

Table B.1.3
Probabilistic Analyses:
Annual Dose (Mean and 95th Percentile)
As a Function of Zone and Age

Zone	Analyte	Medium	Mean (Sv/y) (ratio to bkgd.)	95th Percentile (Sv/y) (ratio to bkgd.)	Ratio of 95th Percentile to Mean
10 year old					
Background	All	Total	1.2E-03 (1.0)	3.2E-03 (1.0)	2.6
	Gamma	GammaRad	1.9E-04 (1.0)	2.4E-04 (1.0)	1.3
	Other	Air	1.4E-05 (1.0)	2.6E-05 (1.0)	1.8
	Other	Fruit	1.9E-06 (1.0)	6.3E-06 (1.0)	3.4
	Other	OtherVeg	7.0E-07 (1.0)	2.7E-06 (1.0)	3.9
	Other	RootVeg	1.1E-06 (1.0)	4.3E-06 (1.0)	3.8
	Other	SoilDust	2.1E-06 (1.0)	7.5E-06 (1.0)	3.6
	Other	Water	1.5E-04 (1.0)	3.6E-04 (1.0)	2.4
	Radon	Radon	8.6E-04 (1.0)	2.8E-03 (1.0)	3.3
All Deloro	All	Total	1.3E-03 (1.1)	3.0E-03 (0.9)	2.3
	Gamma	GammaRad	2.3E-04 (1.2)	3.0E-04 (1.2)	1.3
	Other	Air	1.1E-05 (0.7)	2.7E-05 (1.0)	2.6
	Other	Fruit	1.1E-06 (0.6)	4.3E-06 (0.7)	3.9
	Other	OtherVeg	4.3E-07 (0.6)	1.7E-06 (0.6)	3.9
	Other	RootVeg	6.9E-07 (0.6)	2.7E-06 (0.6)	3.9
	Other	SoilDust	1.2E-06 (0.6)	4.1E-06 (0.6)	3.5
	Other	Water	1.5E-04 (1.0)	3.6E-04 (1.0)	2.4
	Radon	Radon	9.0E-04 (1.0)	2.5E-03 (0.9)	2.8
Zone 1	All	Total	1.7E-03 (1.4)	4.1E-03 (1.3)	2.4
	Gamma	GammaRad	2.2E-04 (1.1)	2.8E-04 (1.2)	1.3
	Other	Air	8.6E-06 (0.6)	2.2E-05 (0.9)	2.6
	Other	Fruit	1.1E-06 (0.6)	4.0E-06 (0.6)	3.7
	Other	OtherVeg	4.1E-07 (0.6)	1.6E-06 (0.6)	3.9
	Other	RootVeg	6.5E-07 (0.6)	2.4E-06 (0.6)	3.6
	Other	SoilDust	1.1E-06 (0.5)	4.1E-06 (0.6)	3.8
	Other	Water	1.5E-04 (1.0)	3.7E-04 (1.0)	2.5
	Radon	Radon	1.3E-03 (1.6)	3.6E-03 (1.3)	2.7
Zone 2	All	Total	1.1E-03 (0.9)	2.2E-03 (0.7)	2
	Gamma	GammaRad	2.1E-04 (1.1)	2.6E-04 (1.1)	1.2
	Other	Air	1.1E-05 (0.7)	2.7E-05 (1.0)	2.5
	Other	Fruit	1.2E-06 (0.7)	4.4E-06 (0.7)	3.6
	Other	OtherVeg	4.6E-07 (0.7)	1.8E-06 (0.7)	4
	Other	RootVeg	7.5E-07 (0.7)	2.8E-06 (0.7)	3.8
	Other	SoilDust	1.2E-06 (0.6)	4.4E-06 (0.6)	3.5
	Other	Water	1.5E-04 (1.0)	3.7E-04 (1.0)	2.5
	Radon	Radon	7.1E-04 (0.8)	1.8E-03 (0.6)	2.5
Zone 3	All	Total	1.2E-03 (1.0)	2.4E-03 (0.8)	2.1
	Gamma	GammaRad	2.4E-04 (1.2)	3.1E-04 (1.3)	1.3
	Other	Air	1.1E-05 (0.8)	2.7E-05 (1.1)	2.5
	Other	Fruit	1.2E-06 (0.6)	4.6E-06 (0.7)	3.9
	Other	OtherVeg	4.7E-07 (0.7)	1.7E-06 (0.6)	3.6
	Other	RootVeg	7.6E-07 (0.7)	2.8E-06 (0.7)	3.7
	Other	SoilDust	1.3E-06 (0.6)	4.4E-06 (0.6)	3.4
	Other	Water	1.5E-04 (1.0)	3.8E-04 (1.1)	2.4
	Radon	Radon	7.7E-04 (0.9)	2.0E-03 (0.7)	2.7
Zone 4	All	Total	2.9E-03 (2.4)	6.7E-03 (2.1)	2.3
	Gamma	GammaRad	2.7E-04 (1.4)	3.0E-04 (1.3)	1.1
	Other	Air	1.2E-05 (0.8)	3.2E-05 (1.2)	2.7
	Other	Fruit	1.1E-06 (0.6)	4.0E-06 (0.6)	3.6
	Other	OtherVeg	4.2E-07 (0.6)	1.7E-06 (0.6)	3.9
	Other	RootVeg	7.0E-07 (0.6)	2.6E-06 (0.6)	3.7
	Other	SoilDust	1.1E-06 (0.5)	3.9E-06 (0.5)	3.5
	Other	Water	1.5E-04 (1.0)	3.5E-04 (1.0)	2.3
	Radon	Radon	2.5E-03 (2.9)	6.2E-03 (2.2)	2.5

Table B.1.3
Probabilistic Analyses:
Annual Dose (Mean and 95th Percentile)
As a Function of Zone and Age

Zone	Analyte	Medium	Mean (Sv/y) (ratio to bkgd.)	95th Percentile (Sv/y) (ratio to bkgd.)	Ratio of 95th Percentile to Mean
15 year old					
Background	All	Total	1.2E-03 (1.0)	3.0E-03 (1.0)	2.5
	Gamma	GammaRad	1.7E-04 (1.0)	2.1E-04 (1.0)	1.3
	Other	Air	1.4E-05 (1.0)	2.9E-05 (1.0)	2
	Other	Fruit	2.1E-06 (1.0)	8.0E-06 (1.0)	3.7
	Other	OtherVeg	9.8E-07 (1.0)	3.9E-06 (1.0)	4
	Other	RootVeg	1.9E-06 (1.0)	7.0E-06 (1.0)	3.7
	Other	SoilDust	1.4E-06 (1.0)	3.1E-06 (1.0)	2.2
	Other	Water	2.1E-04 (1.0)	5.4E-04 (1.0)	2.6
	Radon	Radon	7.9E-04 (1.0)	2.6E-03 (1.0)	3.3
All Deloro	All	Total	1.2E-03 (1.1)	2.8E-03 (0.9)	2.2
	Gamma	GammaRad	2.0E-04 (1.2)	2.6E-04 (1.2)	1.3
	Other	Air	8.6E-06 (0.6)	2.1E-05 (0.7)	2.5
	Other	Fruit	1.4E-06 (0.6)	5.0E-06 (0.6)	3.7
	Other	OtherVeg	6.1E-07 (0.6)	2.3E-06 (0.6)	3.7
	Other	RootVeg	1.2E-06 (0.6)	4.5E-06 (0.6)	3.8
	Other	SoilDust	7.8E-07 (0.6)	1.6E-06 (0.5)	2.1
	Other	Water	2.0E-04 (1.0)	5.4E-04 (1.0)	2.7
	Radon	Radon	8.3E-04 (1.0)	2.4E-03 (0.9)	2.9
Zone 1	All	Total	1.6E-03 (1.4)	3.8E-03 (1.3)	2.3
	Gamma	GammaRad	1.9E-04 (1.1)	2.5E-04 (1.2)	1.3
	Other	Air	7.1E-06 (0.5)	1.8E-05 (0.6)	2.5
	Other	Fruit	1.3E-06 (0.6)	5.4E-06 (0.7)	4.1
	Other	OtherVeg	5.9E-07 (0.6)	2.2E-06 (0.6)	3.8
	Other	RootVeg	1.2E-06 (0.6)	4.2E-06 (0.6)	3.6
	Other	SoilDust	7.5E-07 (0.5)	1.8E-06 (0.6)	2.4
	Other	Water	2.1E-04 (1.0)	5.4E-04 (1.0)	2.6
	Radon	Radon	1.2E-03 (1.6)	3.5E-03 (1.3)	2.8
Zone 2	All	Total	1.1E-03 (0.9)	2.1E-03 (0.7)	2
	Gamma	GammaRad	1.9E-04 (1.1)	2.3E-04 (1.1)	1.2
	Other	Air	8.7E-06 (0.6)	2.2E-05 (0.8)	2.5
	Other	Fruit	1.4E-06 (0.7)	5.3E-06 (0.7)	3.7
	Other	OtherVeg	6.6E-07 (0.7)	2.2E-06 (0.6)	3.4
	Other	RootVeg	1.3E-06 (0.7)	4.8E-06 (0.7)	3.6
	Other	SoilDust	8.6E-07 (0.6)	1.8E-06 (0.6)	2.1
	Other	Water	2.0E-04 (1.0)	5.2E-04 (1.0)	2.6
	Radon	Radon	6.6E-04 (0.8)	1.7E-03 (0.6)	2.6
Zone 3	All	Total	1.1E-03 (1.0)	2.3E-03 (0.8)	2
	Gamma	GammaRad	2.1E-04 (1.2)	2.8E-04 (1.3)	1.3
	Other	Air	9.2E-06 (0.6)	2.3E-05 (0.8)	2.5
	Other	Fruit	1.5E-06 (0.7)	5.7E-06 (0.7)	3.9
	Other	OtherVeg	6.5E-07 (0.7)	2.4E-06 (0.6)	3.7
	Other	RootVeg	1.3E-06 (0.7)	4.8E-06 (0.7)	3.7
	Other	SoilDust	8.4E-07 (0.6)	1.7E-06 (0.6)	2.1
	Other	Water	2.1E-04 (1.0)	5.7E-04 (1.0)	2.7
	Radon	Radon	7.1E-04 (0.9)	1.9E-03 (0.7)	2.6
Zone 4	All	Total	2.7E-03 (2.3)	6.2E-03 (2.1)	2.3
	Gamma	GammaRad	2.4E-04 (1.4)	2.7E-04 (1.3)	1.1
	Other	Air	9.8E-06 (0.7)	2.7E-05 (0.9)	2.8
	Other	Fruit	1.3E-06 (0.6)	5.0E-06 (0.6)	3.8
	Other	OtherVeg	6.0E-07 (0.6)	2.3E-06 (0.6)	3.8
	Other	RootVeg	1.2E-06 (0.6)	4.3E-06 (0.6)	3.6
	Other	SoilDust	7.6E-07 (0.5)	1.7E-06 (0.6)	2.3
	Other	Water	2.1E-04 (1.0)	5.5E-04 (1.0)	2.7
	Radon	Radon	2.3E-03 (2.9)	5.8E-03 (2.2)	2.5

Table B.1.3
Probabilistic Analyses:
Annual Dose (Mean and 95th Percentile)
As a Function of Zone and Age

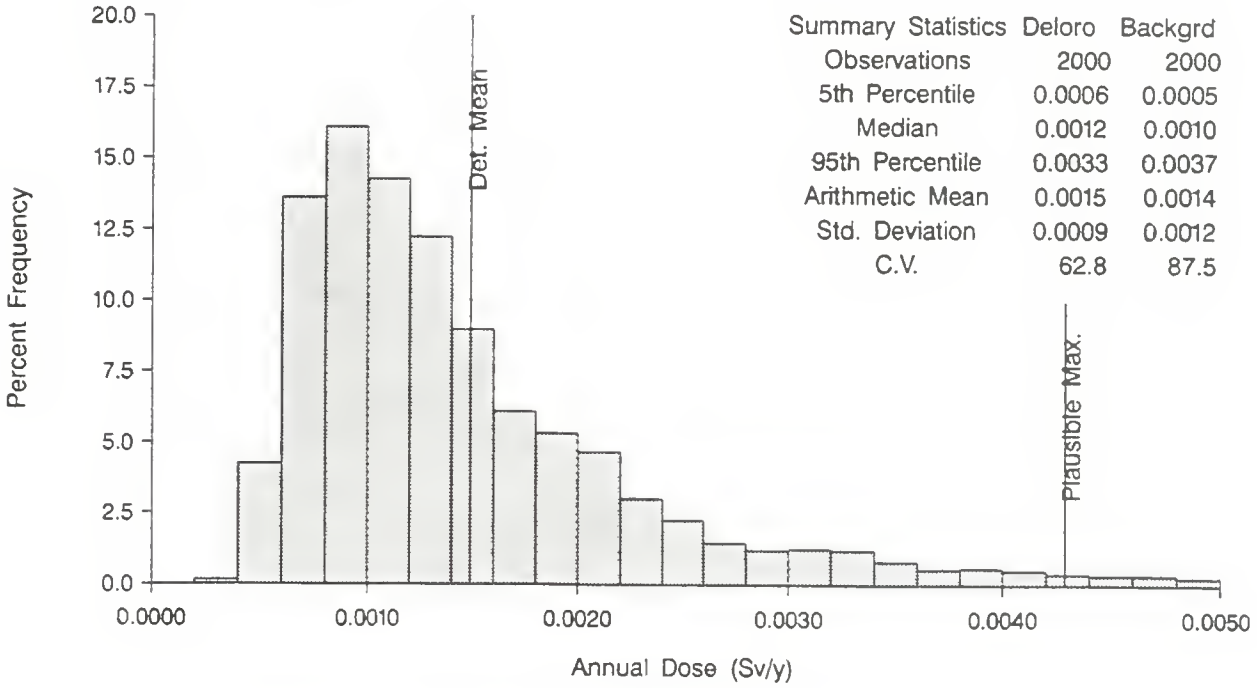
Zone	Analyte	Medium	Mean (Sv/y) (ratio to bkgd.)	95th Percentile (Sv/y) (ratio to bkgd.)	Ratio of 95th Percentile to Mean
Adult					
Background	All	Total	1.1E-03 (1.0)	2.9E-03 (1.0)	2.6
	Gamma	GammaRad	1.6E-04 (1.0)	2.1E-04 (1.0)	1.3
	Other	Air	1.1E-05 (1.0)	2.1E-05 (1.0)	1.9
	Other	Fruit	7.5E-07 (1.0)	2.7E-06 (1.0)	3.6
	Other	OtherVeg	4.5E-07 (1.0)	1.5E-06 (1.0)	3.4
	Other	RootVeg	5.9E-07 (1.0)	2.2E-06 (1.0)	3.8
	Other	SoilDust	7.1E-07 (1.0)	1.6E-06 (1.0)	2.3
	Other	Water	1.1E-04 (1.0)	2.6E-04 (1.0)	2.4
	Radon	Radon	8.1E-04 (1.0)	2.6E-03 (1.0)	3.2
All Deloro	All	Total	1.2E-03 (1.1)	2.7E-03 (0.9)	2.3
	Gamma	GammaRad	2.0E-04 (1.2)	2.6E-04 (1.2)	1.3
	Other	Air	8.2E-06 (0.7)	2.0E-05 (0.9)	2.4
	Other	Fruit	4.2E-07 (0.6)	1.6E-06 (0.6)	3.8
	Other	OtherVeg	2.4E-07 (0.5)	8.5E-07 (0.6)	3.5
	Other	RootVeg	3.4E-07 (0.6)	1.3E-06 (0.6)	3.8
	Other	SoilDust	3.6E-07 (0.5)	7.5E-07 (0.5)	2.1
	Other	Water	1.1E-04 (1.0)	2.8E-04 (1.1)	2.6
	Radon	Radon	8.5E-04 (1.1)	2.4E-03 (0.9)	2.8
Zone 1	All	Total	1.6E-03 (1.4)	3.8E-03 (1.3)	2.4
	Gamma	GammaRad	1.8E-04 (1.1)	2.5E-04 (1.2)	1.3
	Other	Air	6.8E-06 (0.6)	1.8E-05 (0.8)	2.6
	Other	Fruit	4.0E-07 (0.5)	1.6E-06 (0.6)	4
	Other	OtherVeg	2.4E-07 (0.5)	8.8E-07 (0.6)	3.7
	Other	RootVeg	3.2E-07 (0.5)	1.3E-06 (0.6)	3.9
	Other	SoilDust	3.4E-07 (0.5)	8.1E-07 (0.5)	2.4
	Other	Water	1.1E-04 (1.0)	2.6E-04 (1.0)	2.4
	Radon	Radon	1.3E-03 (1.6)	3.5E-03 (1.4)	2.8
Zone 2	All	Total	9.7E-04 (0.9)	2.1E-03 (0.7)	2.1
	Gamma	GammaRad	1.8E-04 (1.1)	2.3E-04 (1.1)	1.3
	Other	Air	8.3E-06 (0.7)	2.0E-05 (1.0)	2.4
	Other	Fruit	4.6E-07 (0.6)	1.6E-06 (0.6)	3.5
	Other	OtherVeg	2.7E-07 (0.6)	9.2E-07 (0.6)	3.4
	Other	RootVeg	3.6E-07 (0.6)	1.3E-06 (0.6)	3.7
	Other	SoilDust	3.9E-07 (0.5)	8.0E-07 (0.5)	2
	Other	Water	1.1E-04 (1.0)	2.7E-04 (1.0)	2.5
	Radon	Radon	6.7E-04 (0.8)	1.7E-03 (0.7)	2.6
Zone 3	All	Total	1.0E-03 (1.0)	2.2E-03 (0.8)	2.1
	Gamma	GammaRad	2.0E-04 (1.2)	2.7E-04 (1.3)	1.3
	Other	Air	8.7E-06 (0.8)	2.1E-05 (1.0)	2.4
	Other	Fruit	4.6E-07 (0.6)	1.7E-06 (0.6)	3.7
	Other	OtherVeg	2.7E-07 (0.6)	9.6E-07 (0.6)	3.5
	Other	RootVeg	3.6E-07 (0.6)	1.3E-06 (0.6)	3.7
	Other	SoilDust	3.9E-07 (0.5)	8.1E-07 (0.5)	2.1
	Other	Water	1.1E-04 (1.0)	2.7E-04 (1.0)	2.5
	Radon	Radon	7.2E-04 (0.9)	1.9E-03 (0.7)	2.6
Zone 4	All	Total	2.7E-03 (2.4)	6.3E-03 (2.2)	2.4
	Gamma	GammaRad	2.3E-04 (1.4)	2.6E-04 (1.3)	1.1
	Other	Air	9.3E-06 (0.8)	2.6E-05 (1.2)	2.8
	Other	Fruit	4.3E-07 (0.6)	1.5E-06 (0.6)	3.5
	Other	OtherVeg	2.6E-07 (0.6)	8.9E-07 (0.6)	3.5
	Other	RootVeg	3.3E-07 (0.6)	1.3E-06 (0.6)	3.8
	Other	SoilDust	3.5E-07 (0.5)	7.6E-07 (0.5)	2.2
	Other	Water	1.1E-04 (1.0)	2.7E-04 (1.0)	2.5
	Radon	Radon	2.3E-03 (2.9)	6.0E-03 (2.3)	2.6

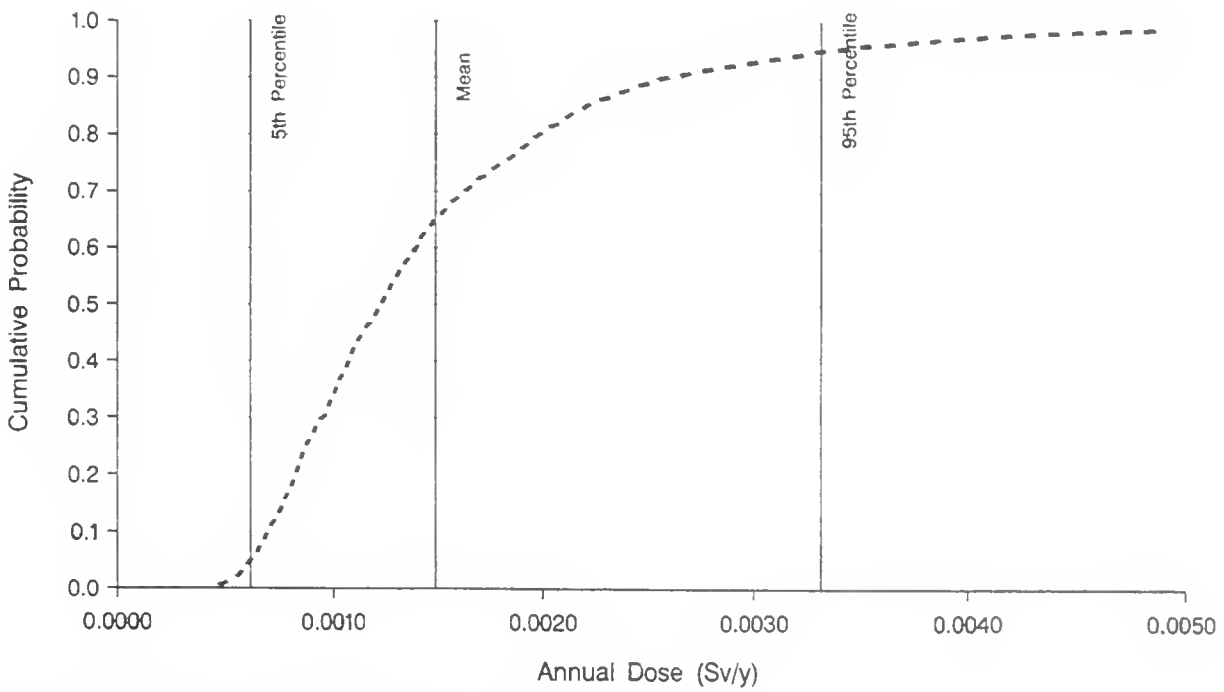
Table B.1.4
Probabilistic Analyses:
Lifetime Risk (Mean and 95th Percentile)
As a Function of Zone

Zone	Analyte	Medium	Mean (ratio to bkgd.)	95th Percentile (ratio to bkgd.)	Ratio of 95th Percentile to Mean
Background	All	Total	6.2E-03 (1.0)	1.6E-02 (1.0)	2.6
	Gamma	GammaRad	9.5E-04 (1.0)	1.2E-03 (1.0)	1.2
	Other	Air	7.6E-05 (1.0)	1.4E-04 (1.0)	1.8
	Other	Fruit	7.2E-06 (1.0)	2.3E-05 (1.0)	3.1
	Other	OtherVeg	3.1E-06 (1.0)	1.0E-05 (1.0)	3.2
	Other	RootVeg	4.9E-06 (1.0)	1.7E-05 (1.0)	3.4
	Other	SoilDust	8.2E-06 (1.0)	1.9E-05 (1.0)	2.3
	Other	Water	7.4E-04 (1.0)	1.5E-03 (1.0)	2.1
	Radon	Radon	4.4E-03 (1.0)	1.5E-02 (1.0)	3.3
All Deloro	All	Total	6.6E-03 (1.1)	1.5E-02 (0.9)	2.3
	Gamma	GammaRad	1.1E-03 (1.2)	1.5E-03 (1.3)	1.3
	Other	Air	5.5E-05 (0.7)	1.3E-04 (1.0)	2.4
	Other	Fruit	4.3E-06 (0.6)	1.5E-05 (0.6)	3.4
	Other	OtherVeg	1.8E-06 (0.6)	6.7E-06 (0.7)	3.7
	Other	RootVeg	2.9E-06 (0.6)	1.0E-05 (0.6)	3.5
	Other	SoilDust	4.6E-06 (0.6)	1.0E-05 (0.6)	2.3
	Other	Water	7.4E-04 (1.0)	1.6E-03 (1.0)	2.2
	Radon	Radon	4.7E-03 (1.1)	1.3E-02 (0.9)	2.8
Zone 1	All	Total	8.8E-03 (1.4)	2.1E-02 (1.3)	2.4
	Gamma	GammaRad	1.1E-03 (1.1)	1.4E-03 (1.2)	1.3
	Other	Air	4.5E-05 (0.6)	1.1E-04 (0.8)	2.5
	Other	Fruit	4.1E-06 (0.6)	1.4E-05 (0.6)	3.4
	Other	OtherVeg	1.8E-06 (0.6)	6.4E-06 (0.6)	3.6
	Other	RootVeg	2.8E-06 (0.6)	1.0E-05 (0.6)	3.6
	Other	SoilDust	4.3E-06 (0.5)	1.1E-05 (0.6)	2.6
	Other	Water	7.4E-04 (1.0)	1.6E-03 (1.0)	2.1
	Radon	Radon	7.0E-03 (1.6)	1.9E-02 (1.3)	2.8
Zone 2	All	Total	5.5E-03 (0.9)	1.1E-02 (0.7)	2
	Gamma	GammaRad	1.1E-03 (1.1)	1.3E-03 (1.1)	1.2
	Other	Air	5.6E-05 (0.7)	1.4E-04 (1.0)	2.4
	Other	Fruit	4.6E-06 (0.6)	1.5E-05 (0.7)	3.2
	Other	OtherVeg	2.0E-06 (0.6)	6.7E-06 (0.7)	3.4
	Other	RootVeg	3.1E-06 (0.6)	1.0E-05 (0.6)	3.3
	Other	SoilDust	4.9E-06 (0.6)	1.2E-05 (0.6)	2.3
	Other	Water	7.3E-04 (1.0)	1.5E-03 (1.0)	2.1
	Radon	Radon	3.7E-03 (0.8)	9.4E-03 (0.6)	2.6
Zone 3	All	Total	6.0E-03 (1.0)	1.3E-02 (0.8)	2.1
	Gamma	GammaRad	1.2E-03 (1.2)	1.5E-03 (1.3)	1.3
	Other	Air	5.8E-05 (0.8)	1.4E-04 (1.0)	2.4
	Other	Fruit	4.6E-06 (0.6)	1.5E-05 (0.7)	3.3
	Other	OtherVeg	2.0E-06 (0.6)	7.2E-06 (0.7)	3.6
	Other	RootVeg	3.1E-06 (0.6)	1.0E-05 (0.6)	3.4
	Other	SoilDust	4.9E-06 (0.6)	1.1E-05 (0.6)	2.3
	Other	Water	7.5E-04 (1.0)	1.6E-03 (1.0)	2.1
	Radon	Radon	4.0E-03 (0.9)	1.1E-02 (0.7)	2.7
Zone 4	All	Total	1.5E-02 (2.4)	3.5E-02 (2.1)	2.3
	Gamma	GammaRad	1.3E-03 (1.4)	1.5E-03 (1.3)	1.1
	Other	Air	6.2E-05 (0.8)	1.7E-04 (1.3)	2.7
	Other	Fruit	4.3E-06 (0.6)	1.4E-05 (0.6)	3.2
	Other	OtherVeg	1.9E-06 (0.6)	6.2E-06 (0.6)	3.3
	Other	RootVeg	2.9E-06 (0.6)	1.0E-05 (0.6)	3.5
	Other	SoilDust	4.4E-06 (0.5)	1.1E-05 (0.6)	2.4
	Other	Water	7.4E-04 (1.0)	1.6E-03 (1.0)	2.1
	Radon	Radon	1.3E-02 (2.9)	3.2E-02 (2.2)	2.6

Figure B.2.1

Distribution of Annual Dose (Sv/y) for 1 Year Old from All Radiological Sources in Deloro

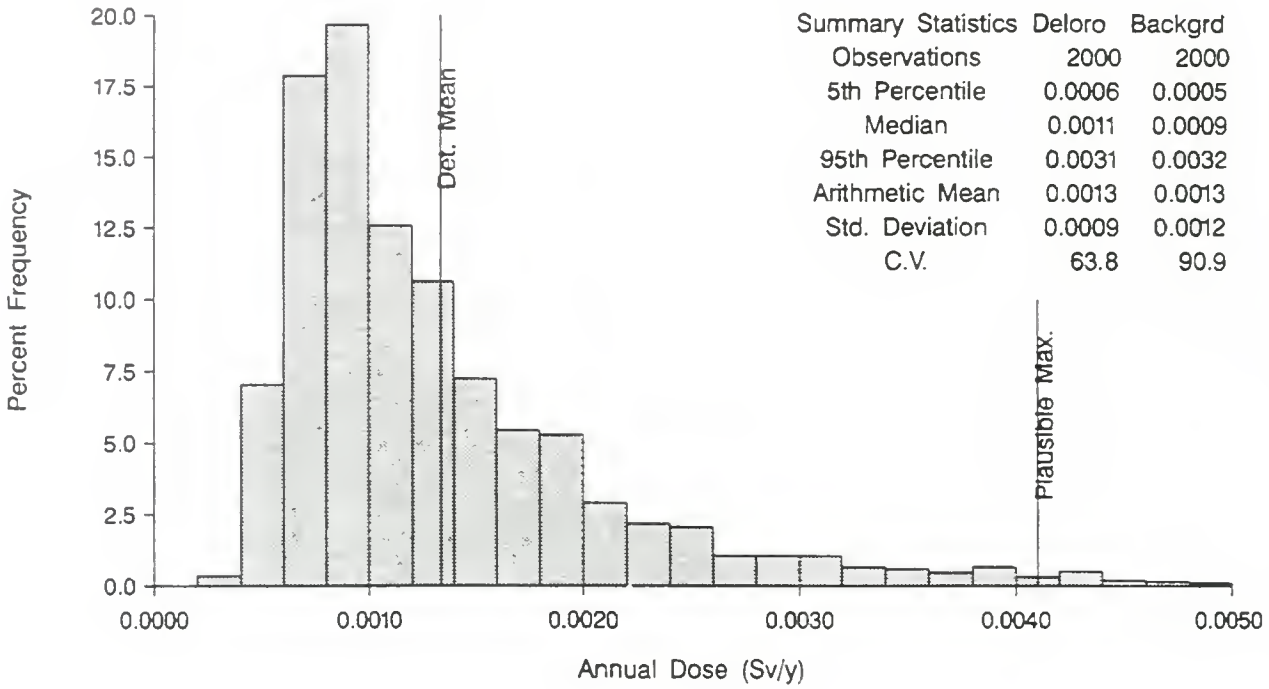


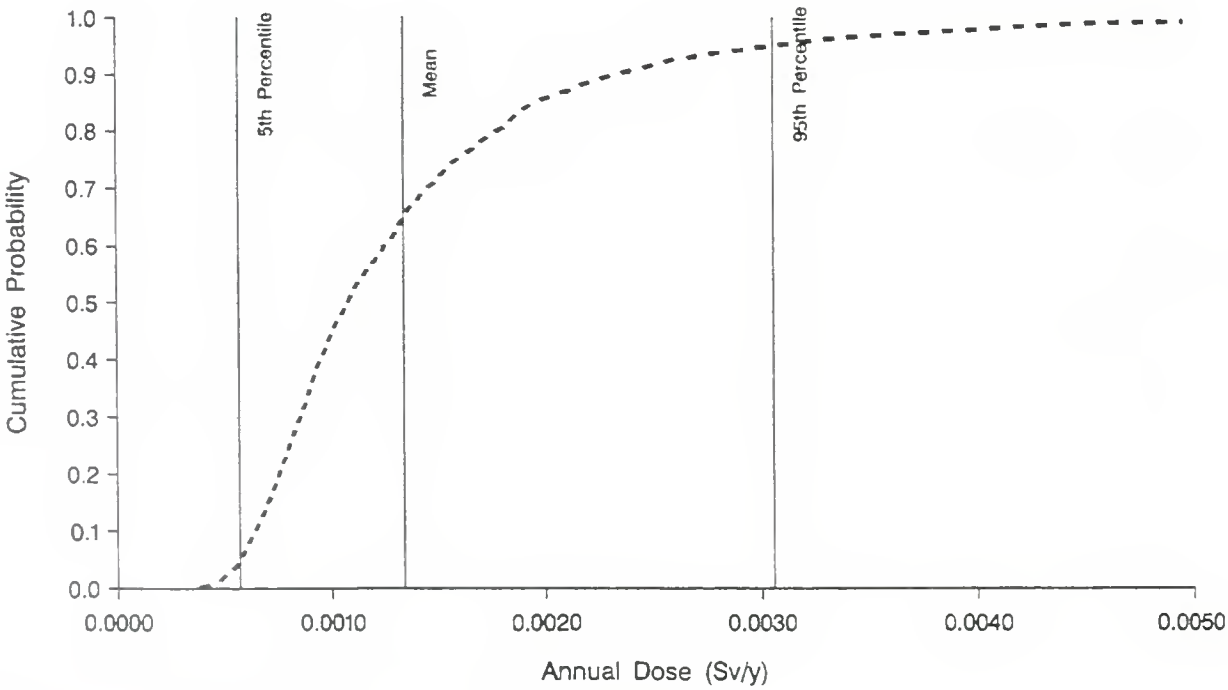


Horizontal axis was truncated at 99th percentile and 17 obs. were not shown.

Figure B.2.2

Distribution of Annual Dose (Sv/y) for 5 Year Old from All Radiological Sources in Deloro

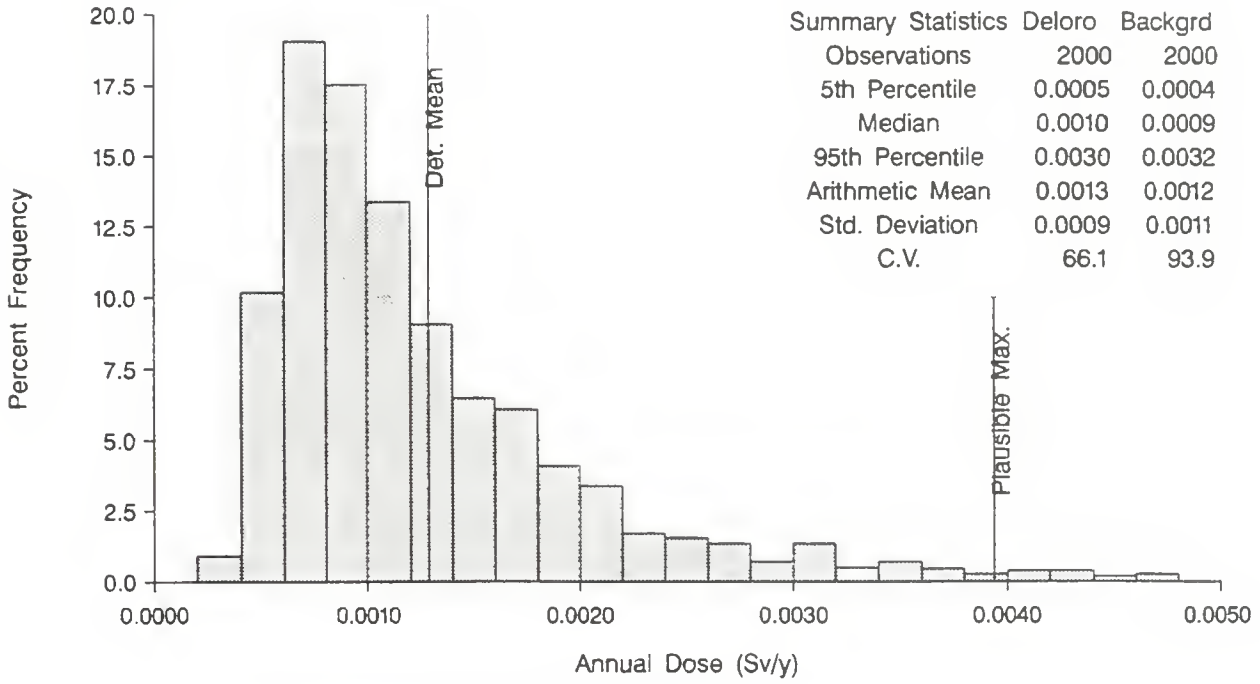


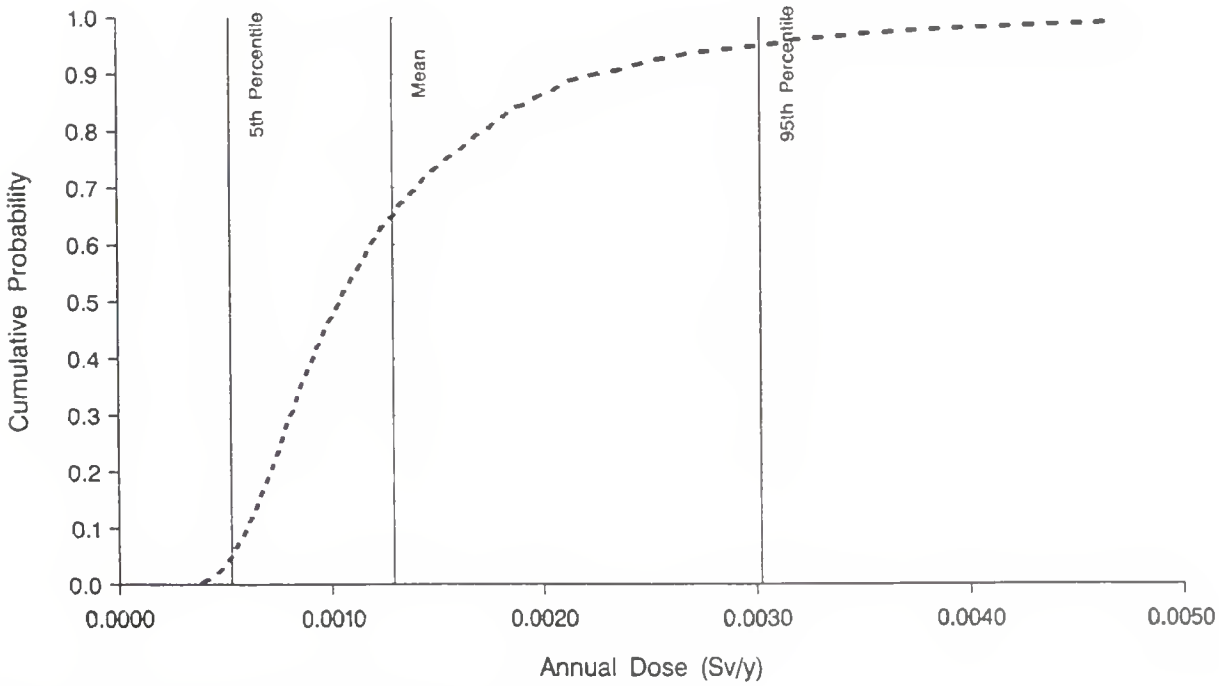


Horizontal axis was truncated at 99th percentile and 12 obs. were not shown.

Figure B.2.3

Distribution of Annual Dose (Sv/y) for 10 Year Old from All Radiological Sources in Deloro

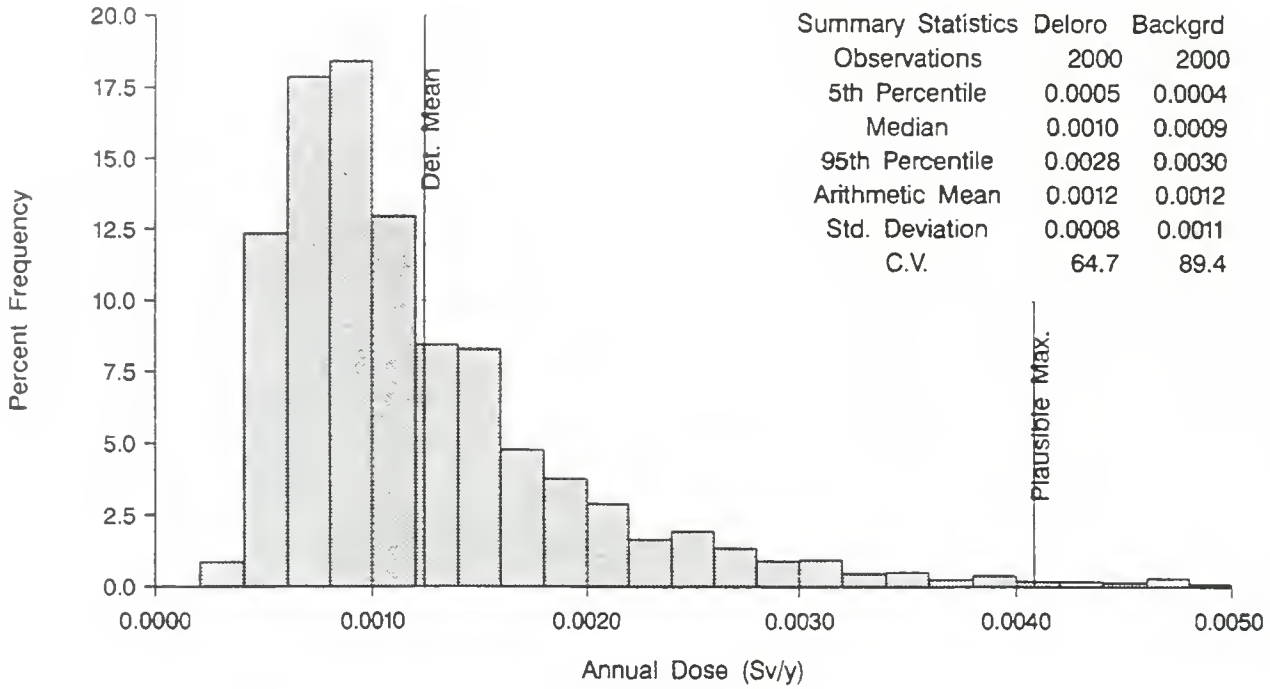


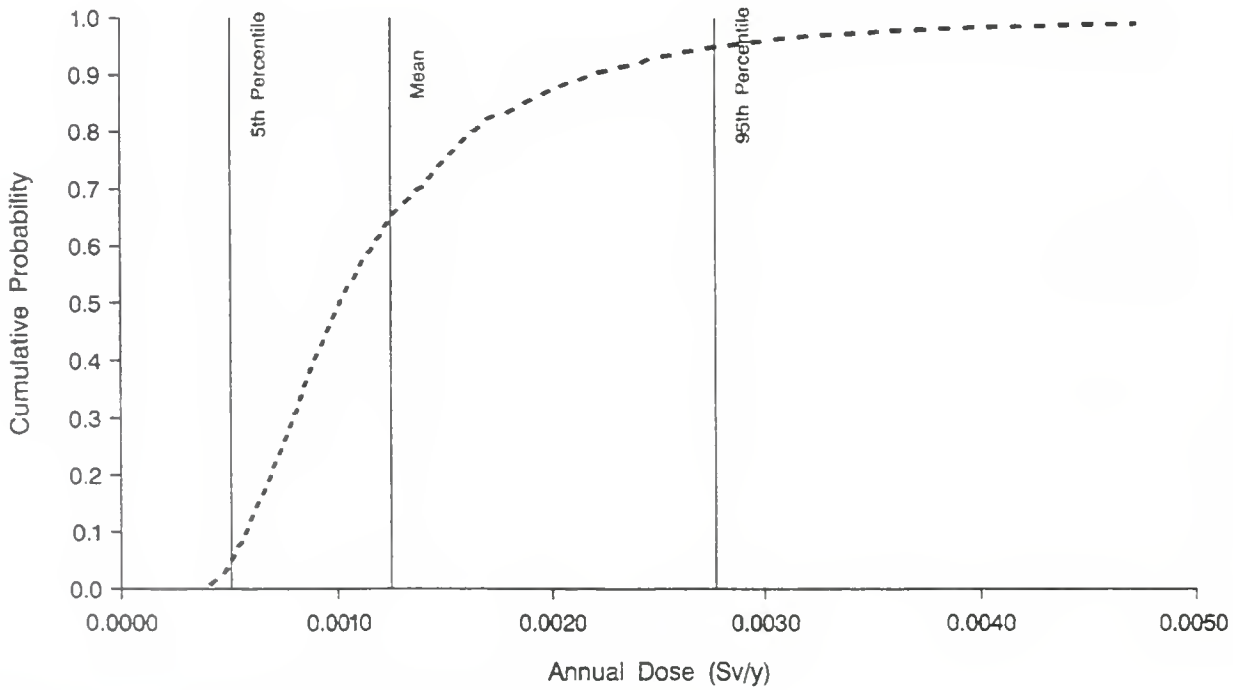


Horizontal axis was truncated at 99th percentile and 13 obs. were not shown.

Figure B.2.4

Distribution of Annual Dose (Sv/y) for 15 Year Old from All Radiological Sources in Deloro

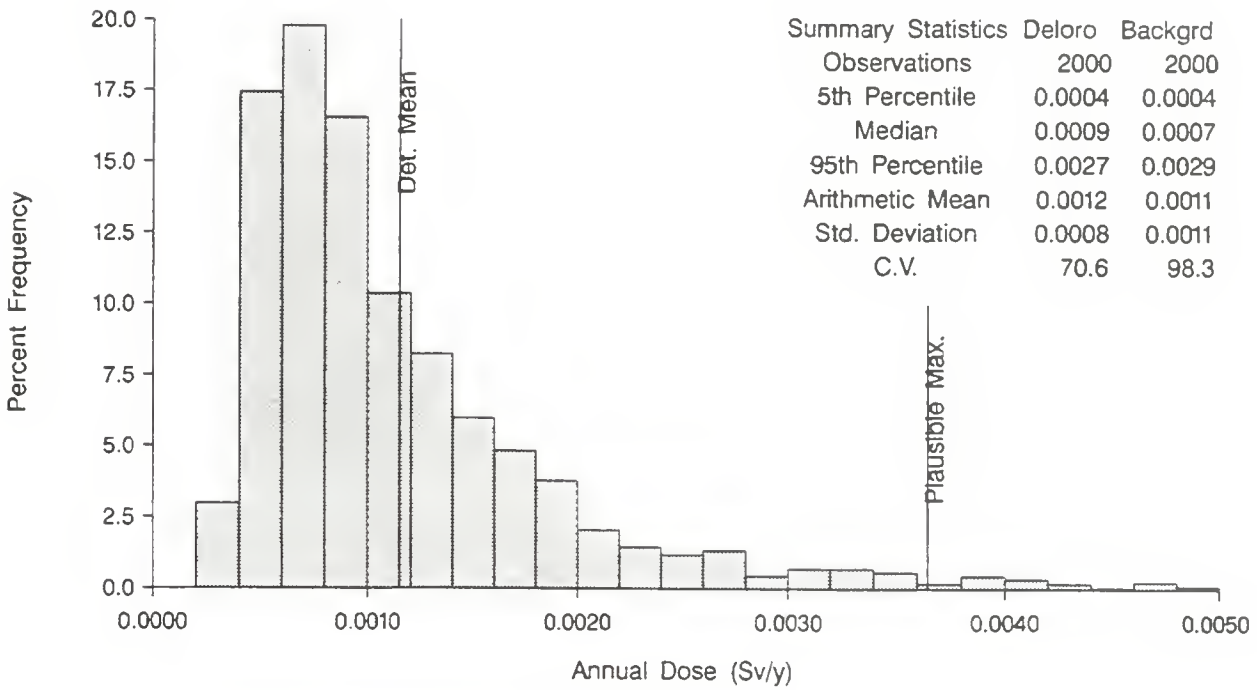


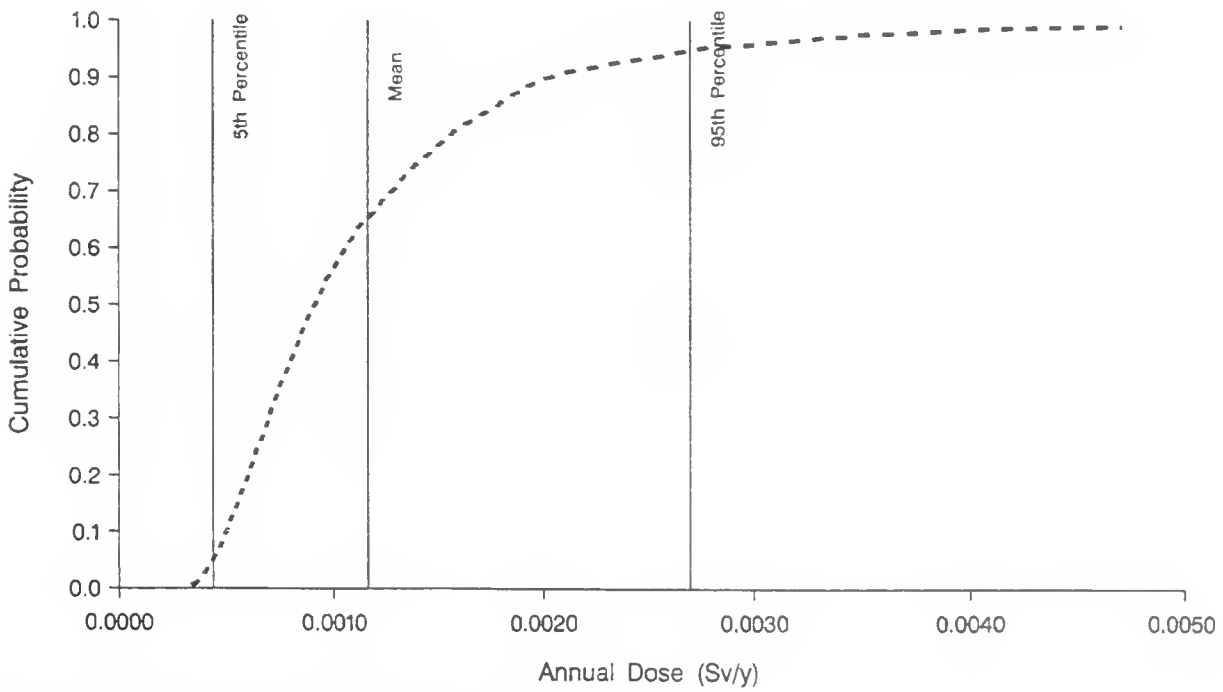


Horizontal axis was truncated at 99th percentile and 10 obs. were not shown.

Figure B.2.5

Distribution of Annual Dose (Sv/y) for Adult from All Radiological Sources in Deloro

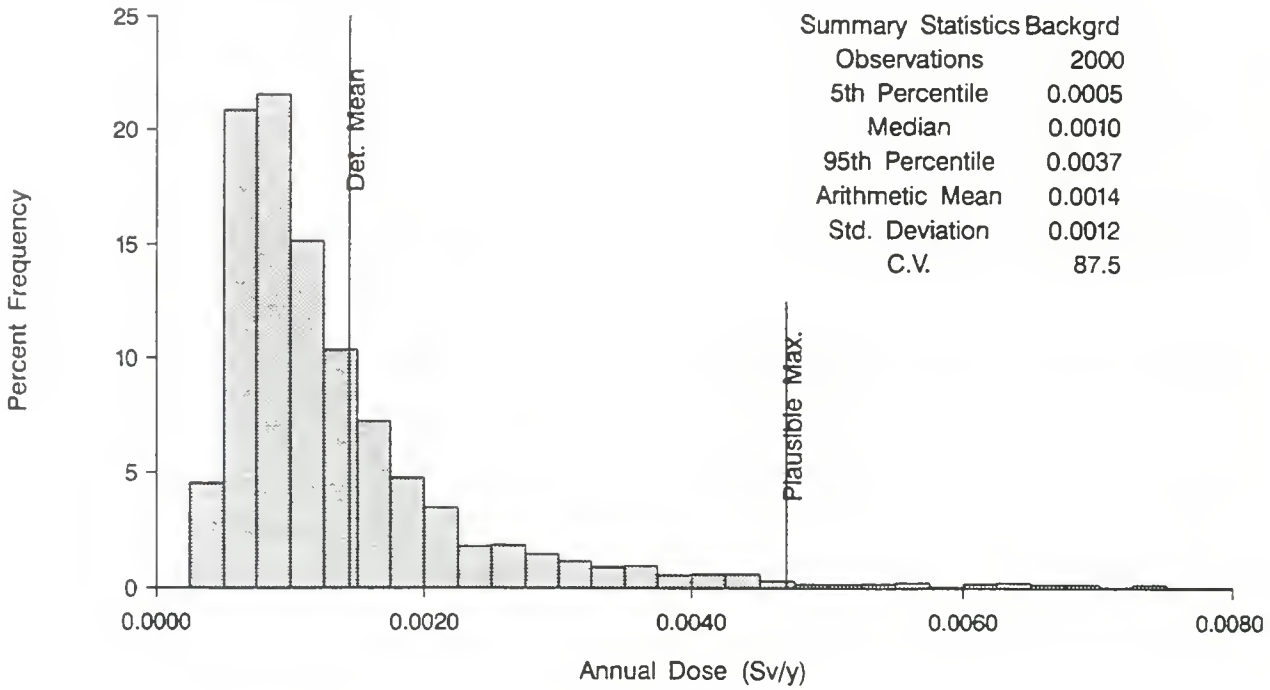


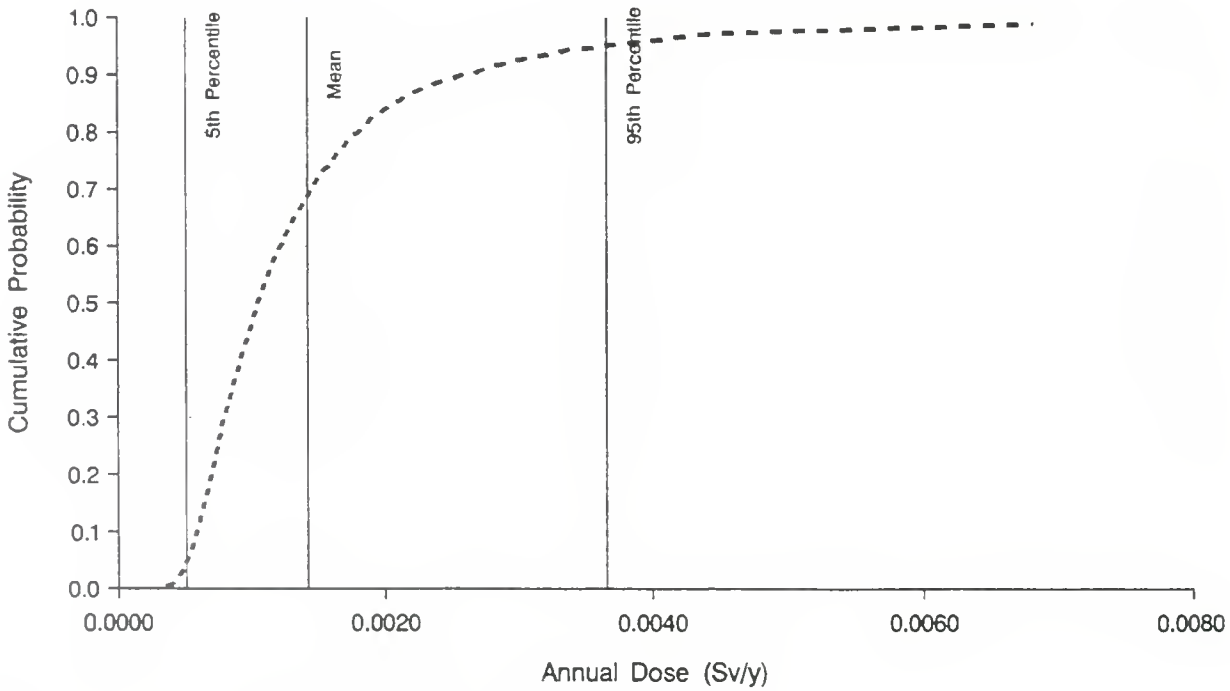


Honzontal axis was truncated at 99th percentile and 9 obs. were not shown.

Figure B.2.6

Distribution of Annual Dose (Sv/y) for 1 Year Old from All Radiological Sources in Background

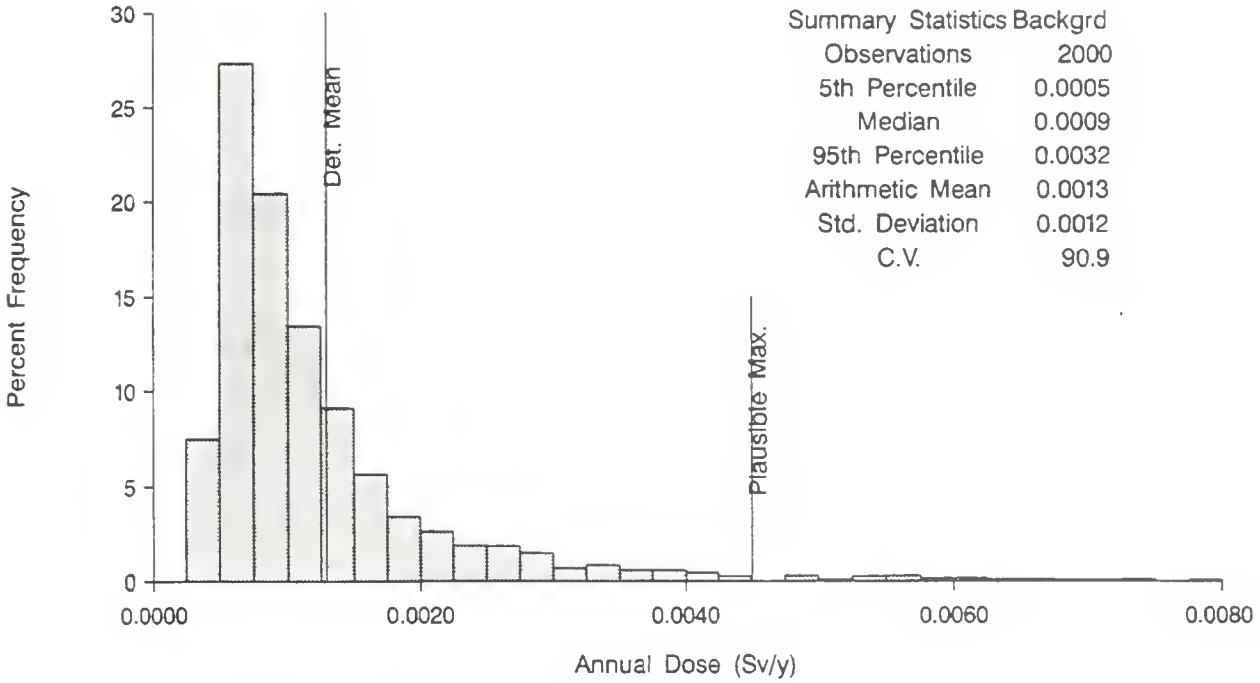


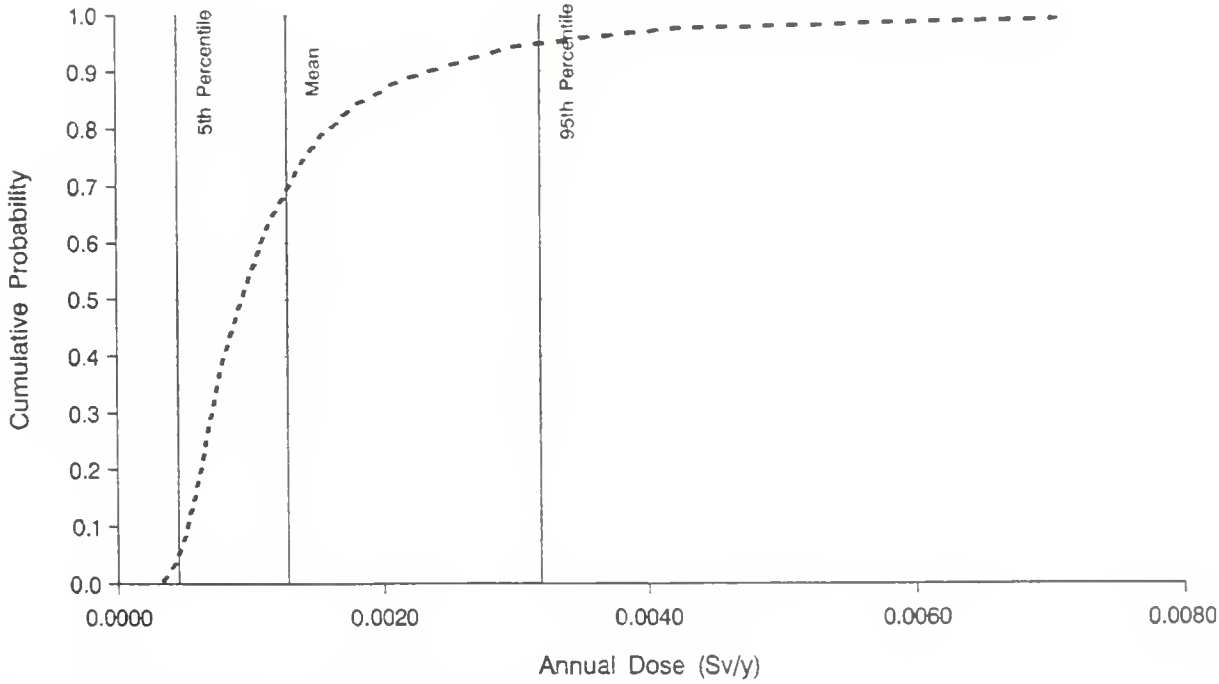


Honzontal axis was truncated at 99th percentile and 10 obs. were not shown.

Figure B.2.7

Distribution of Annual Dose (Sv/y) for 5 Year Old from All Radiological Sources in Background

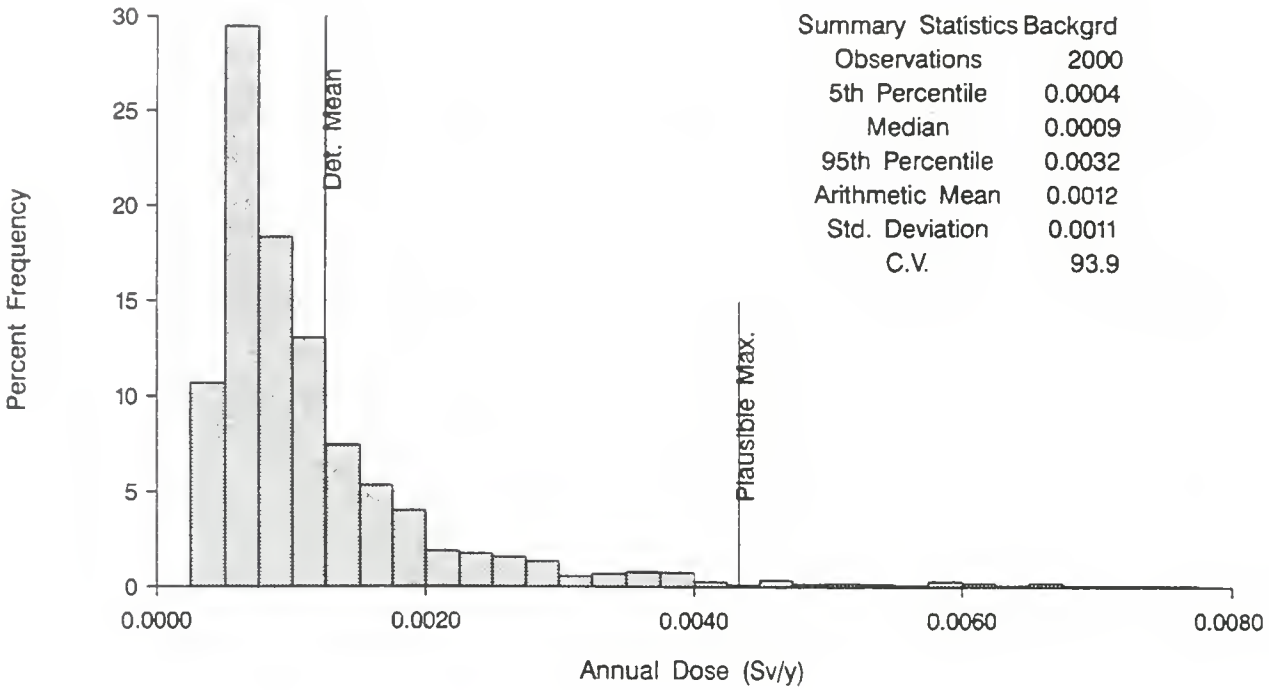


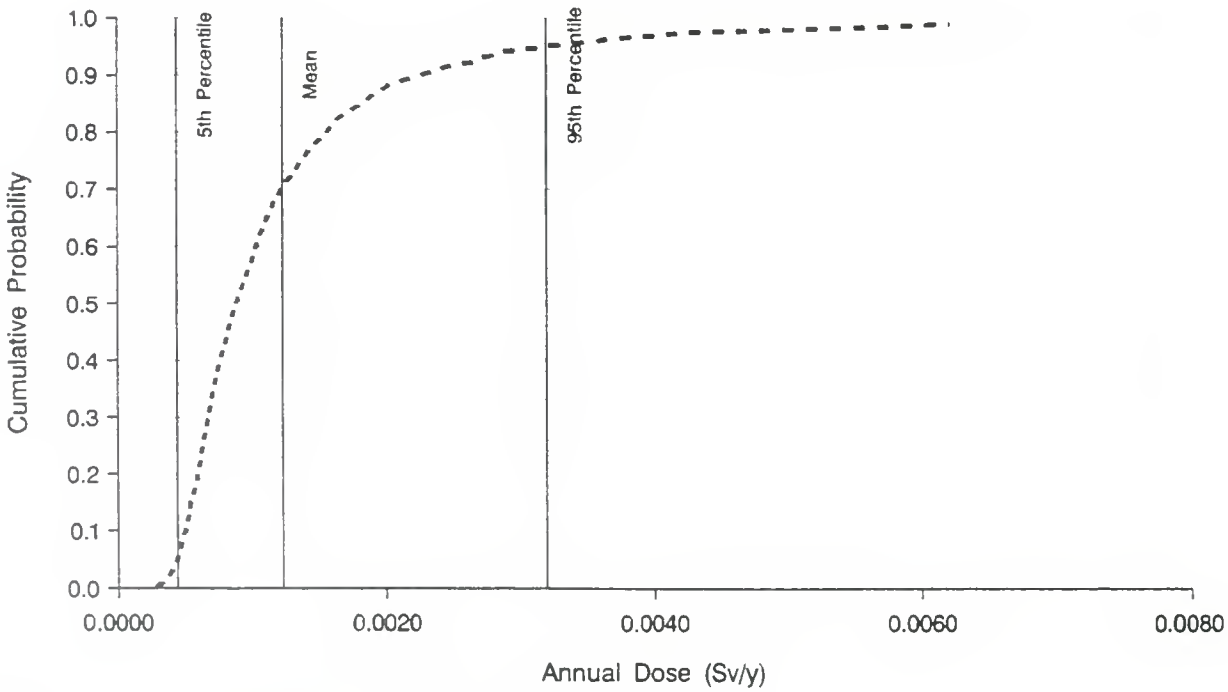


Horizontal axis was truncated at 99th percentile and 9 obs. were not shown.

Figure B.2.8

Distribution of Annual Dose (Sv/y) for 10 Year Old from All Radiological Sources in Background

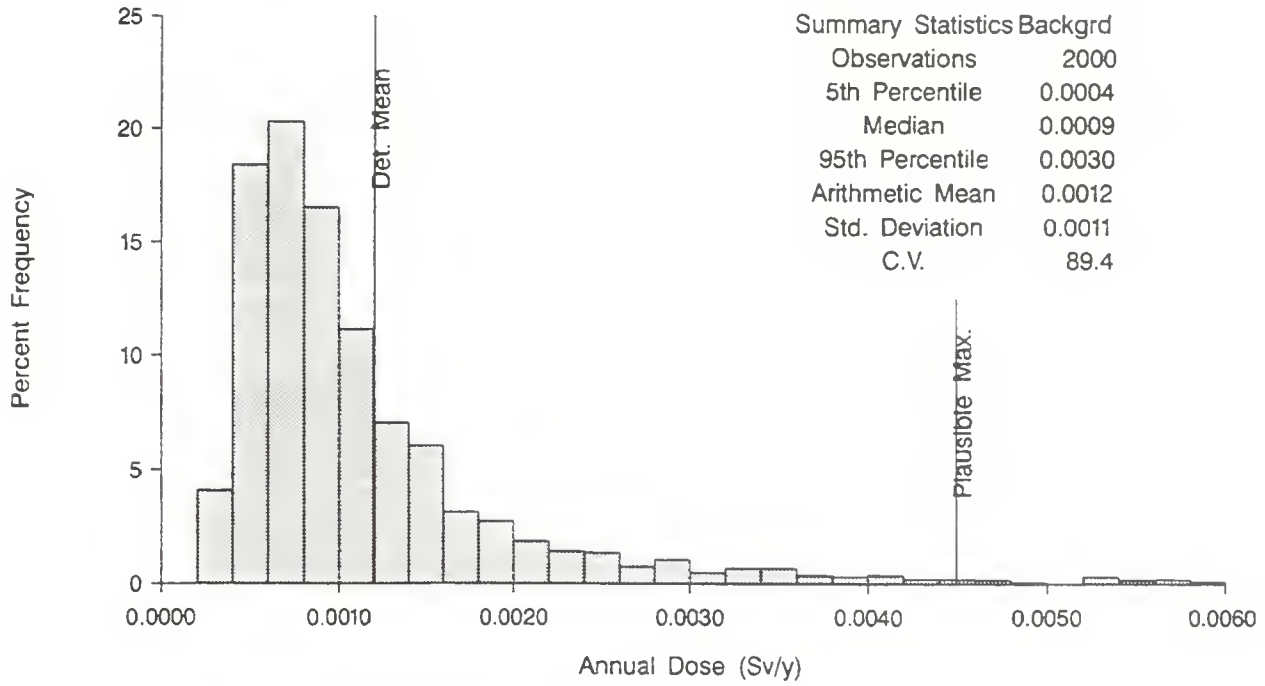


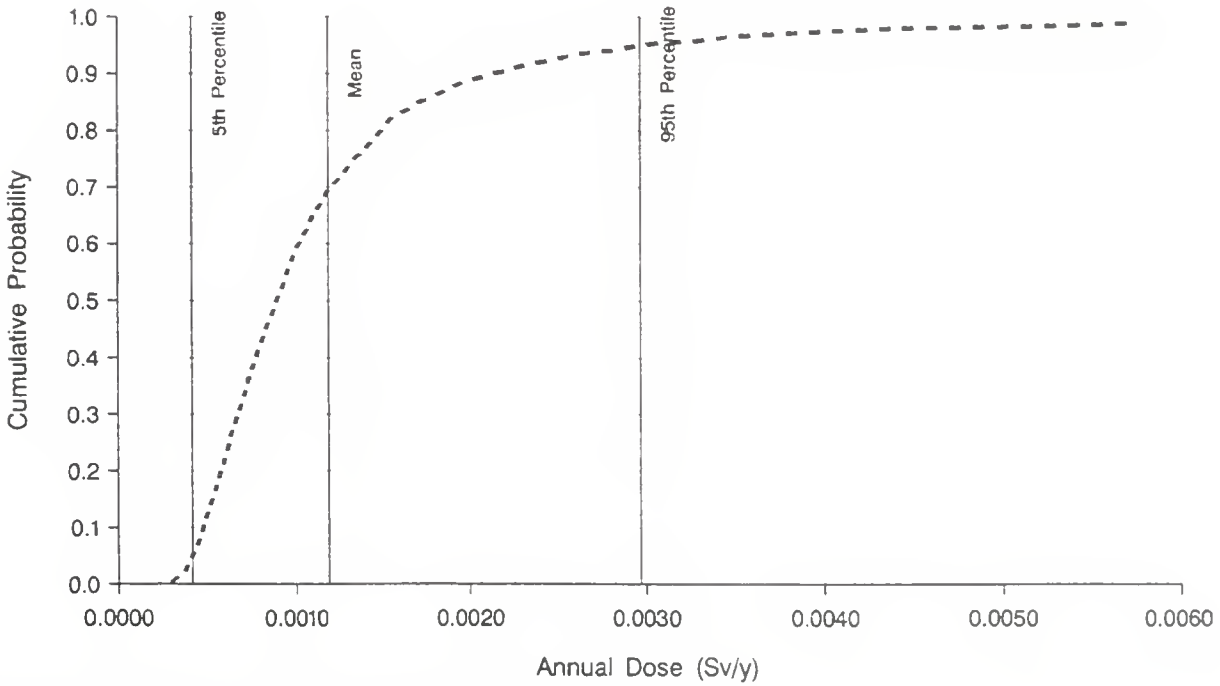


Horizontal axis was truncated at 99th percentile and 8 obs. were not shown.

Figure B.2.9

Distribution of Annual Dose (Sv/y) for 15 Year Old from All Radiological Sources in Background

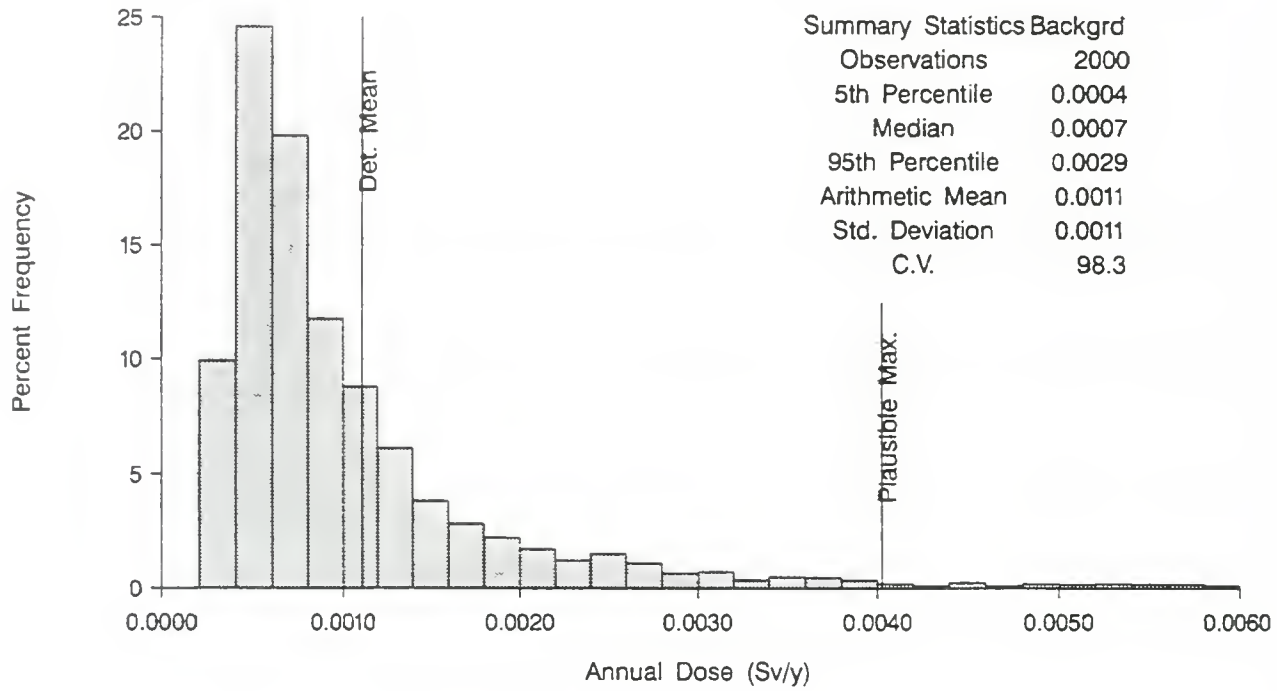


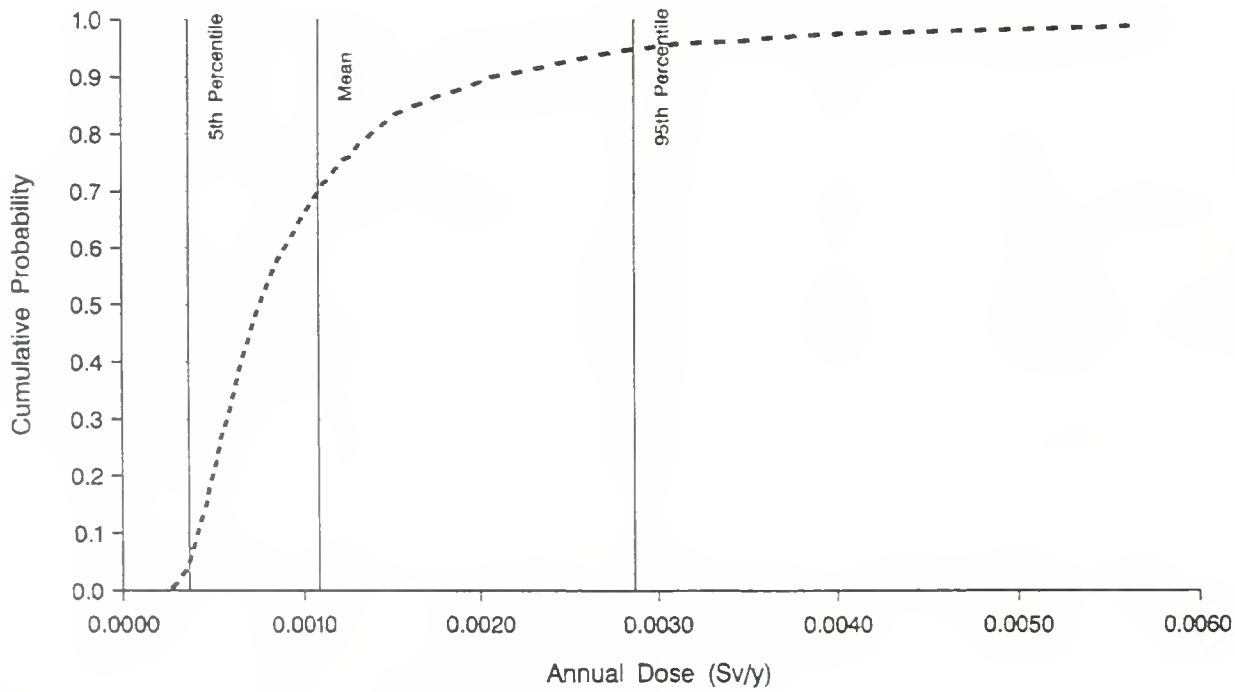


Horizontal axis was truncated at 99th percentile and 16 obs. were not shown.

Figure B.2.10

Distribution of Annual Dose (Sv/y) for Adult from All Radiological Sources in Background

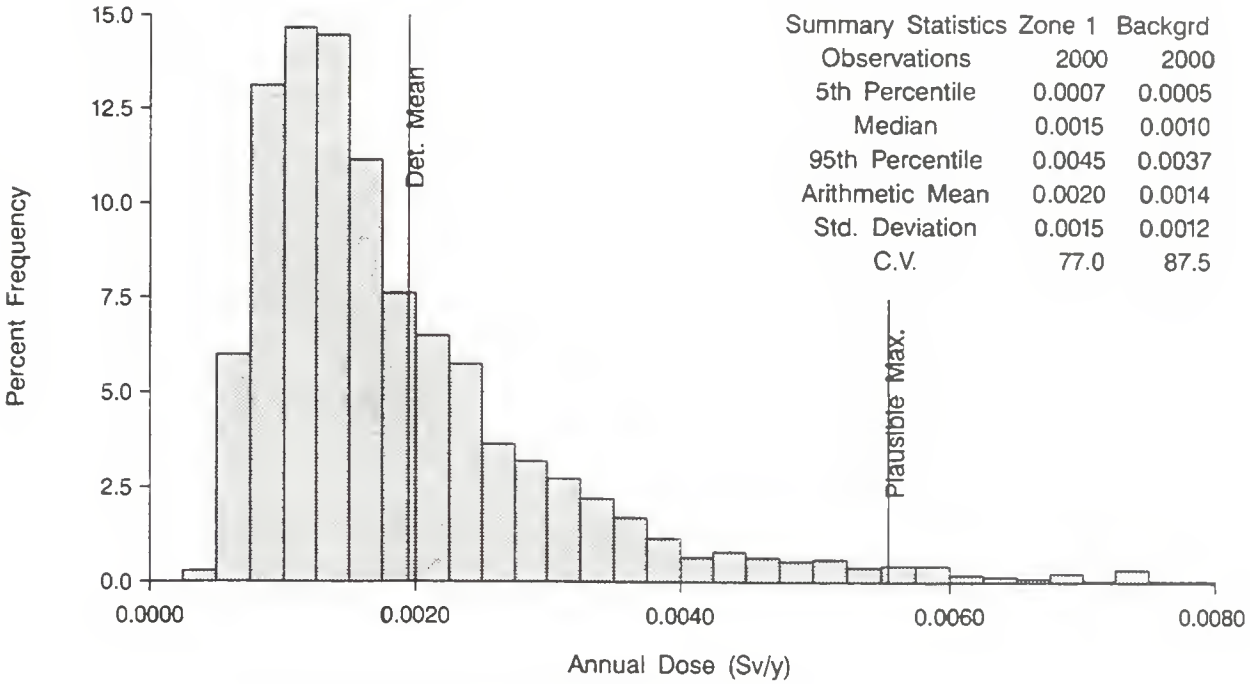


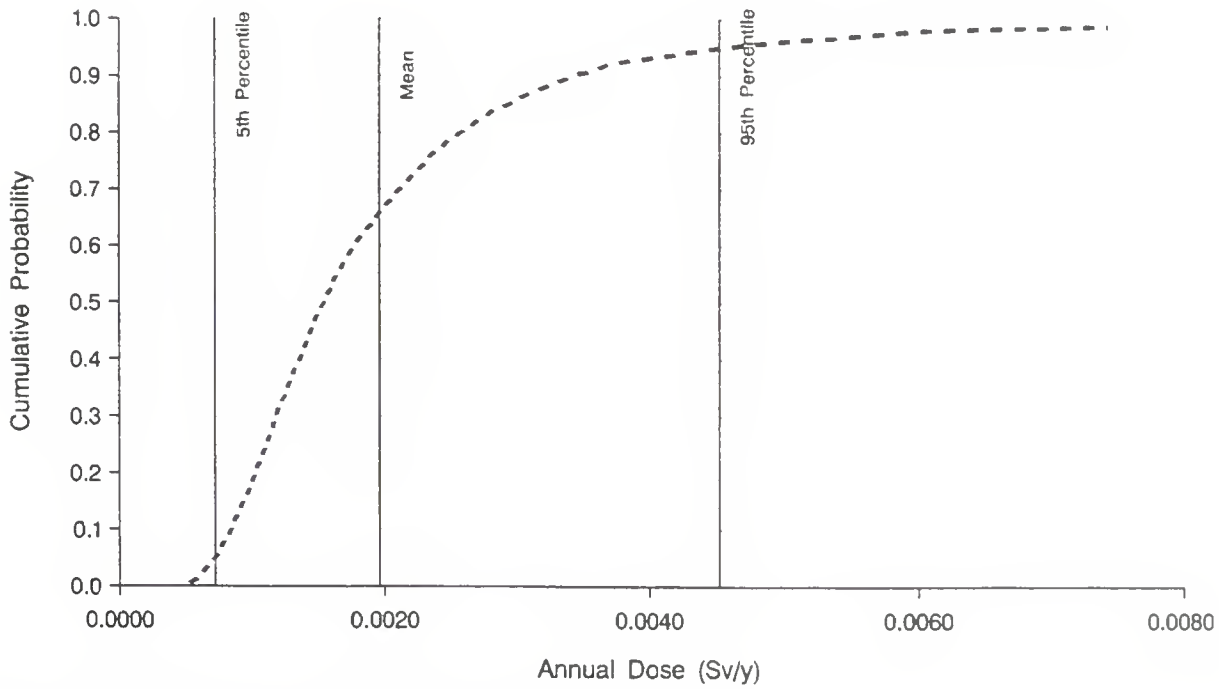


Honzontal axis was truncated at 99th percentile and 15 obs. were not shown.

Figure B.2.11

Distribution of Annual Dose (Sv/y) for 1 Year Old from All Radiological Sources in Zone 1

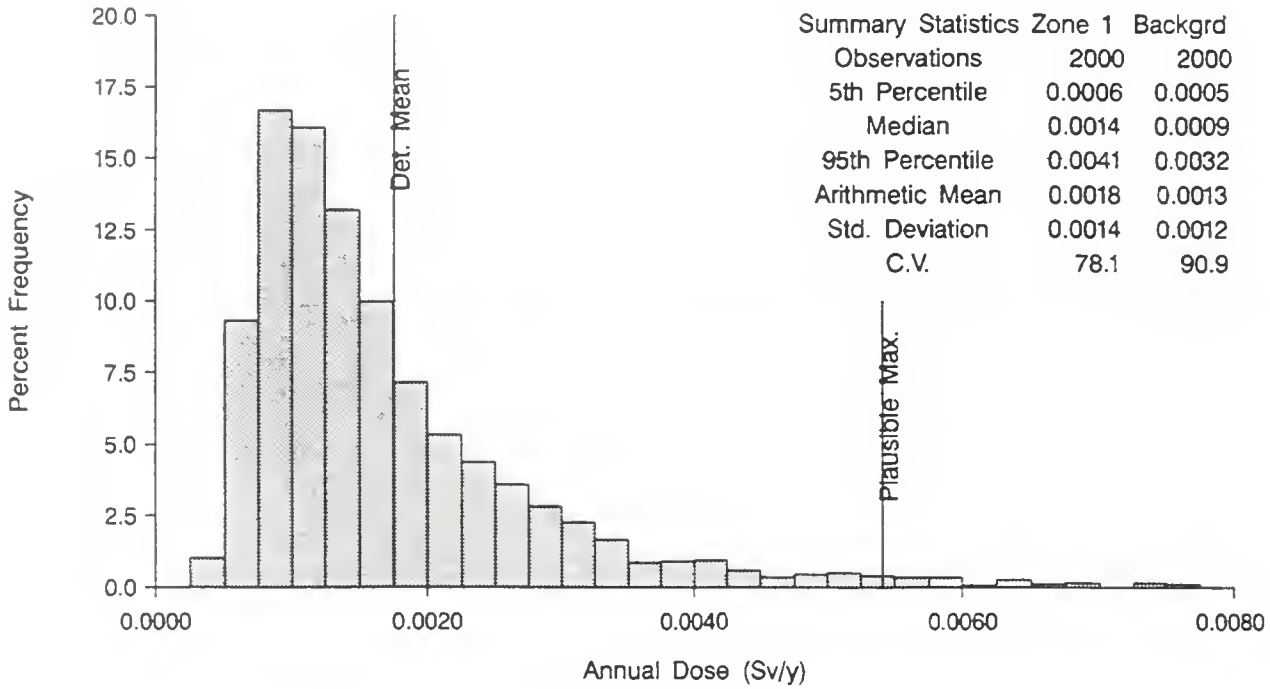


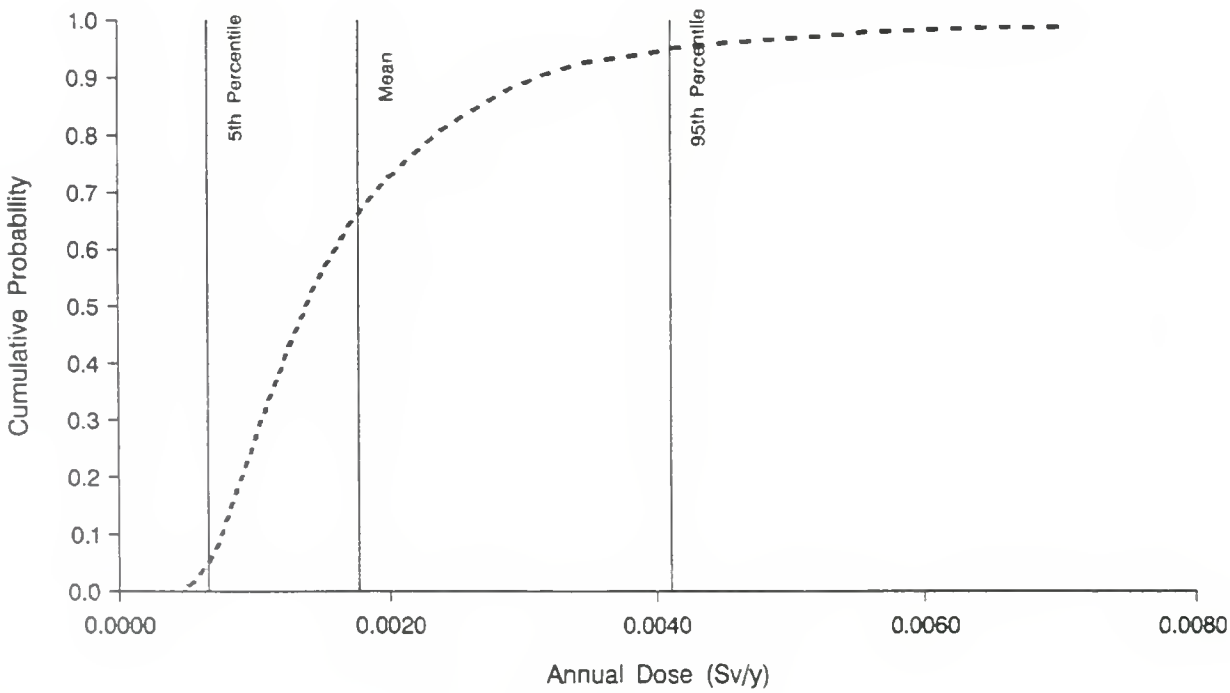


Horizontal axis was truncated at 99th percentile and 17 obs. were not shown.

Figure B.2.12

Distribution of Annual Dose (Sv/y) for 5 Year Old from All Radiological Sources in Zone 1

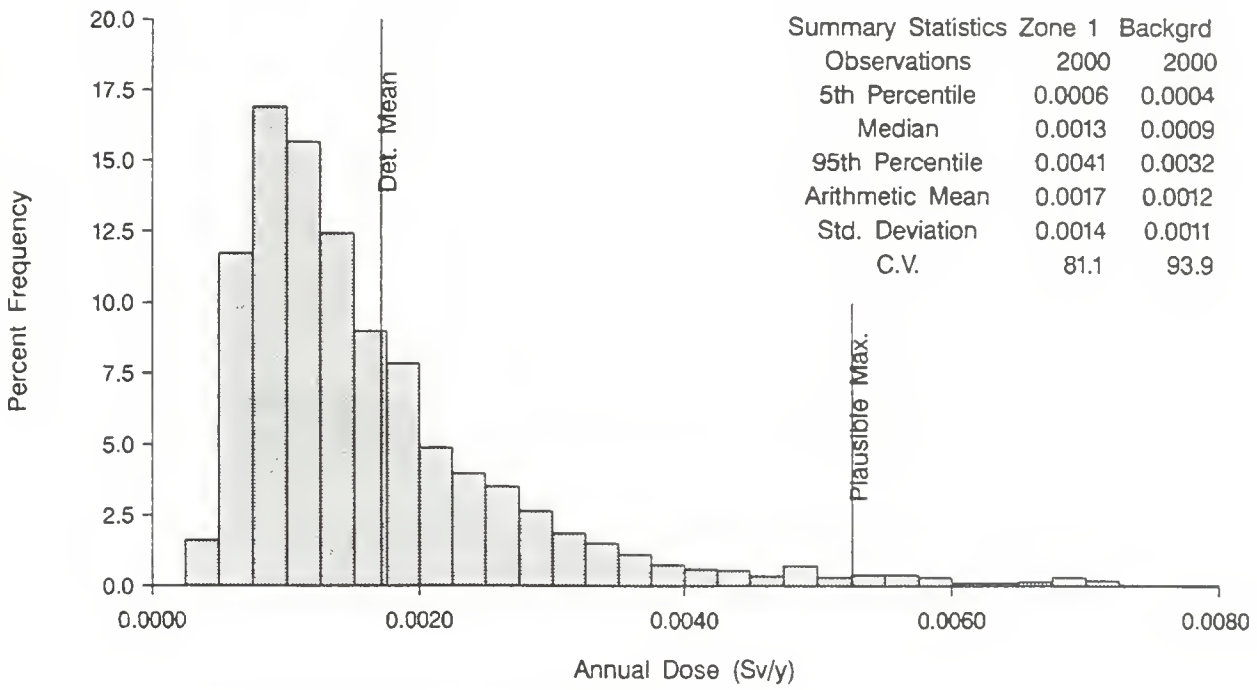


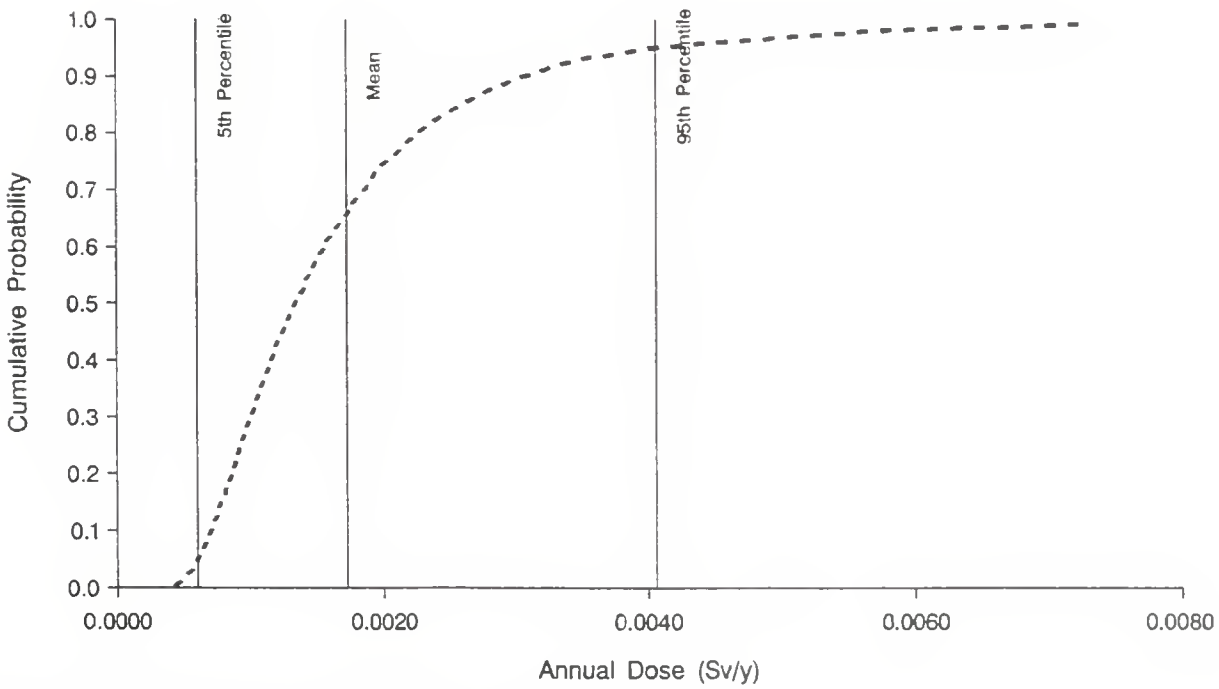


Horizontal axis was truncated at 99th percentile and 15 obs. were not shown.

Figure B.2.13

Distribution of Annual Dose (Sv/y) for 10 Year Old from All Radiological Sources in Zone 1

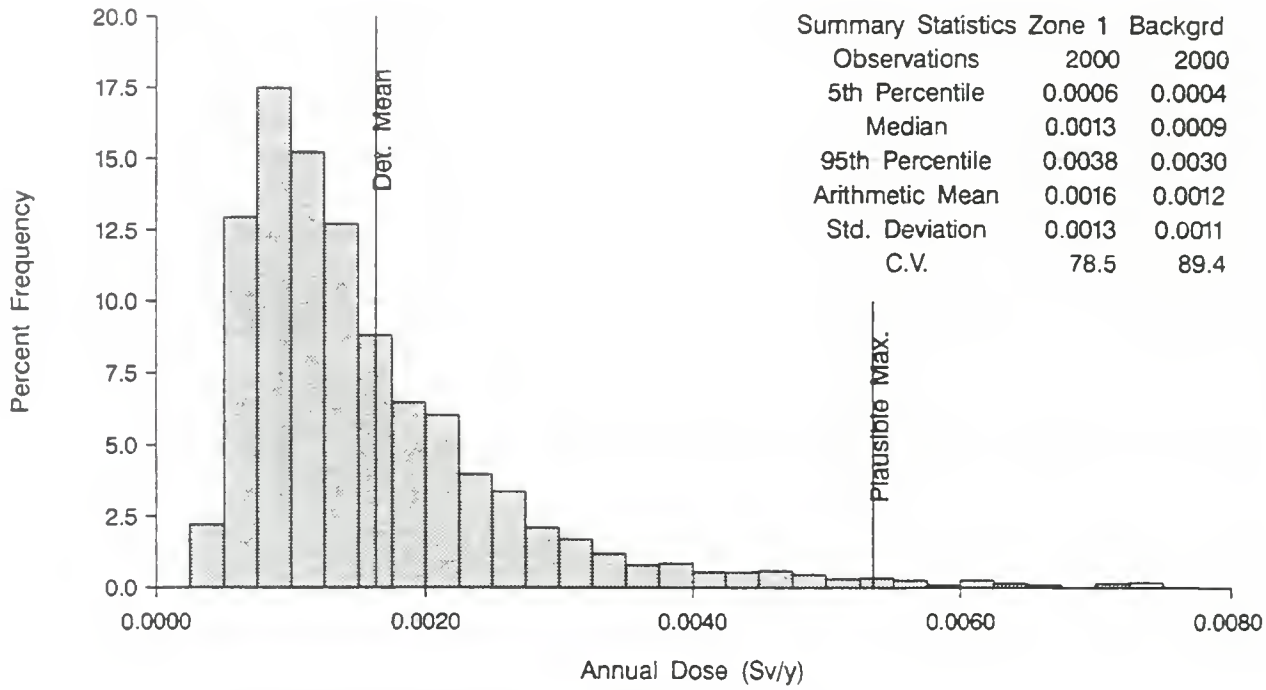


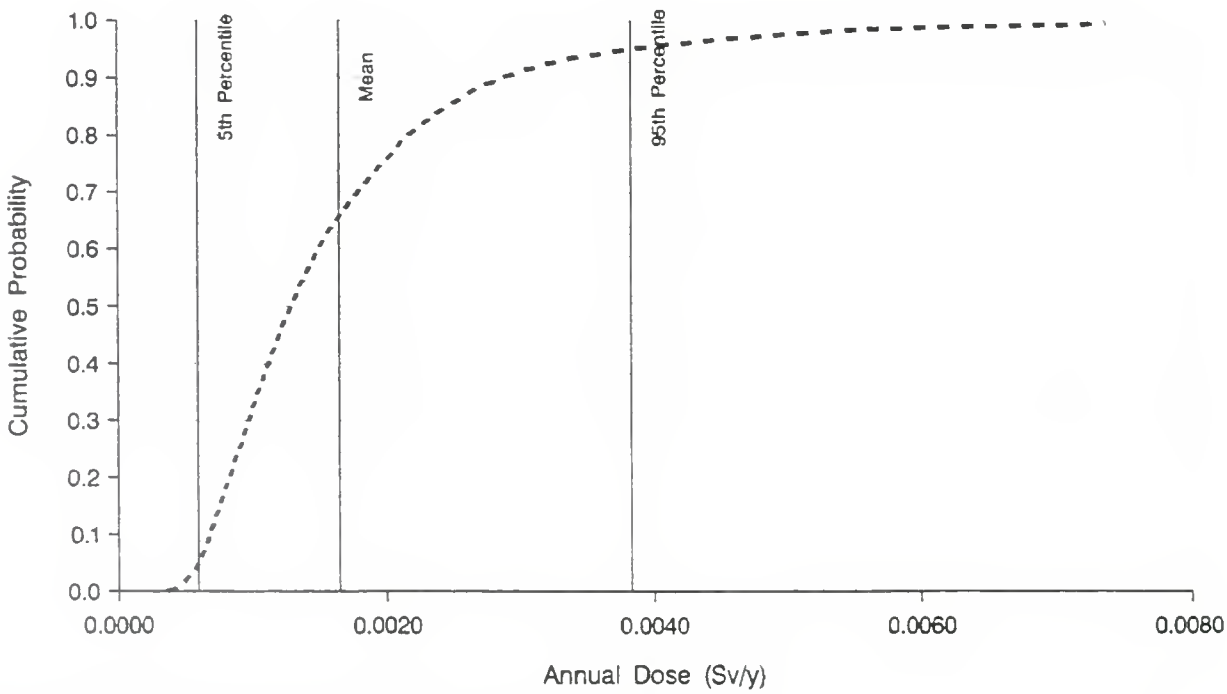


Horizontal axis was truncated at 99th percentile and 11 obs. were not shown.

Figure B.2.14

Distribution of Annual Dose (Sv/y) for 15 Year Old from All Radiological Sources in Zone 1

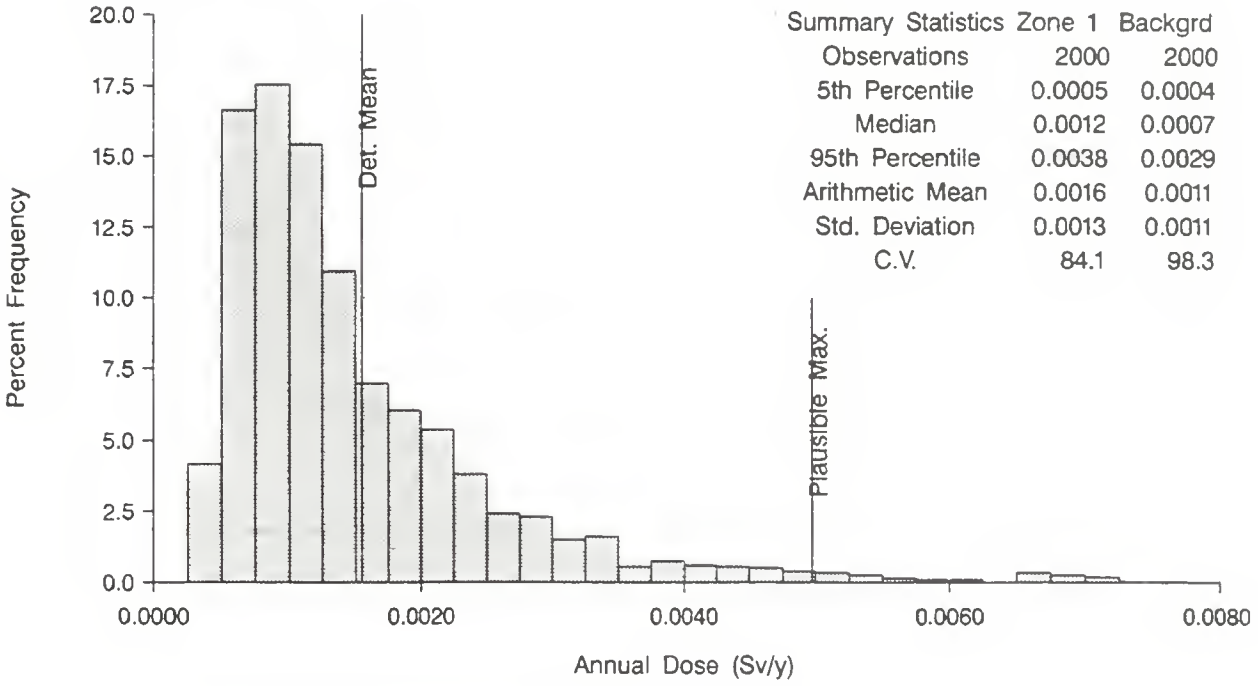


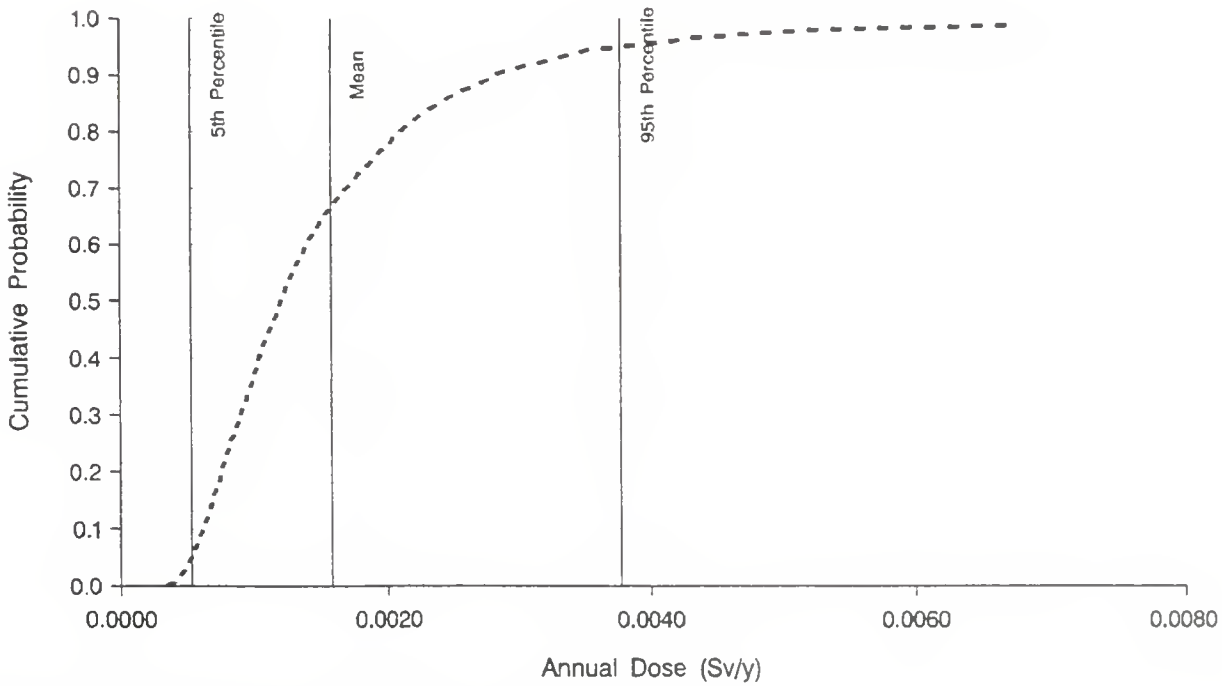


Horizontal axis was truncated at 99th percentile and 10 obs. were not shown.

Figure B.2.15

Distribution of Annual Dose (Sv/y) for Adult from All Radiological Sources in Zone 1

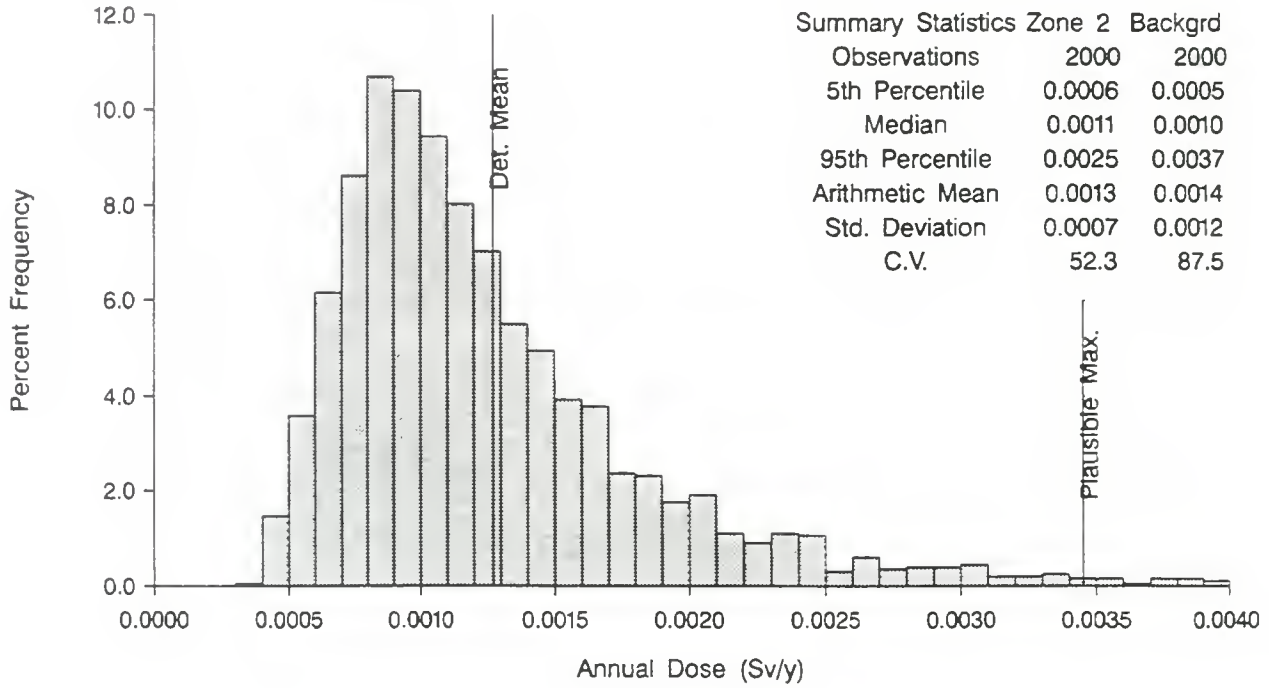


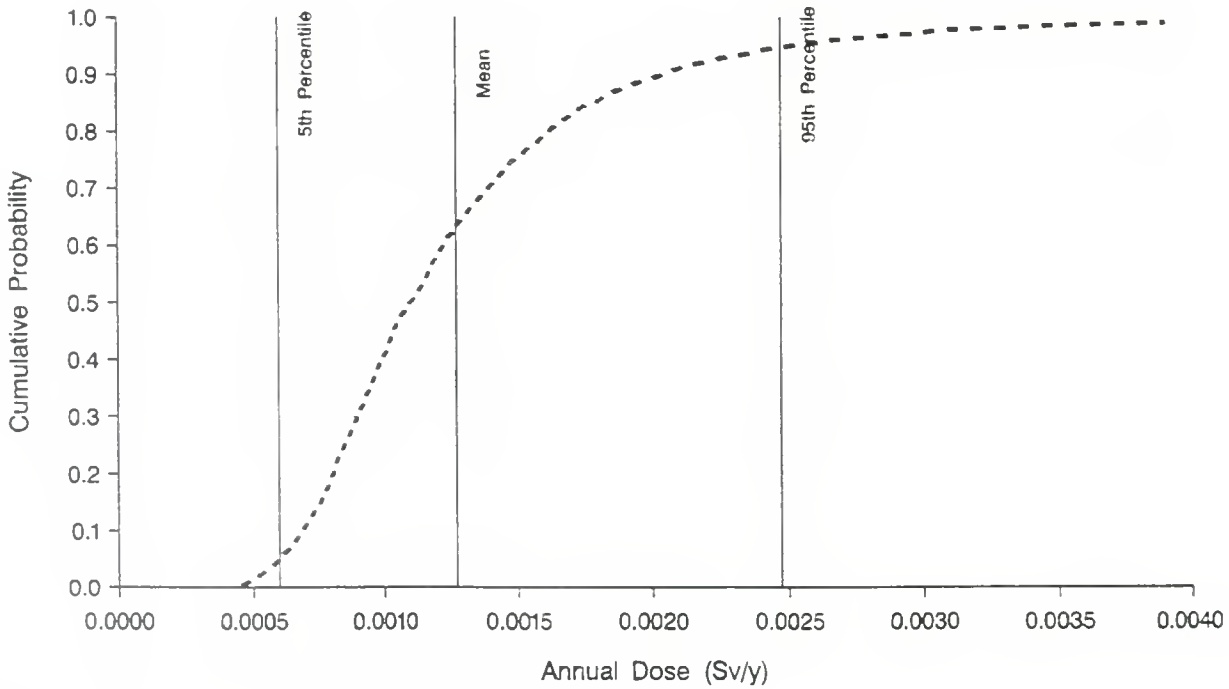


Horizontal axis was truncated at 99th percentile and 10 obs. were not shown.

Figure B.2.16

Distribution of Annual Dose (Sv/y) for 1 Year Old from All Radiological Sources in Zone 2

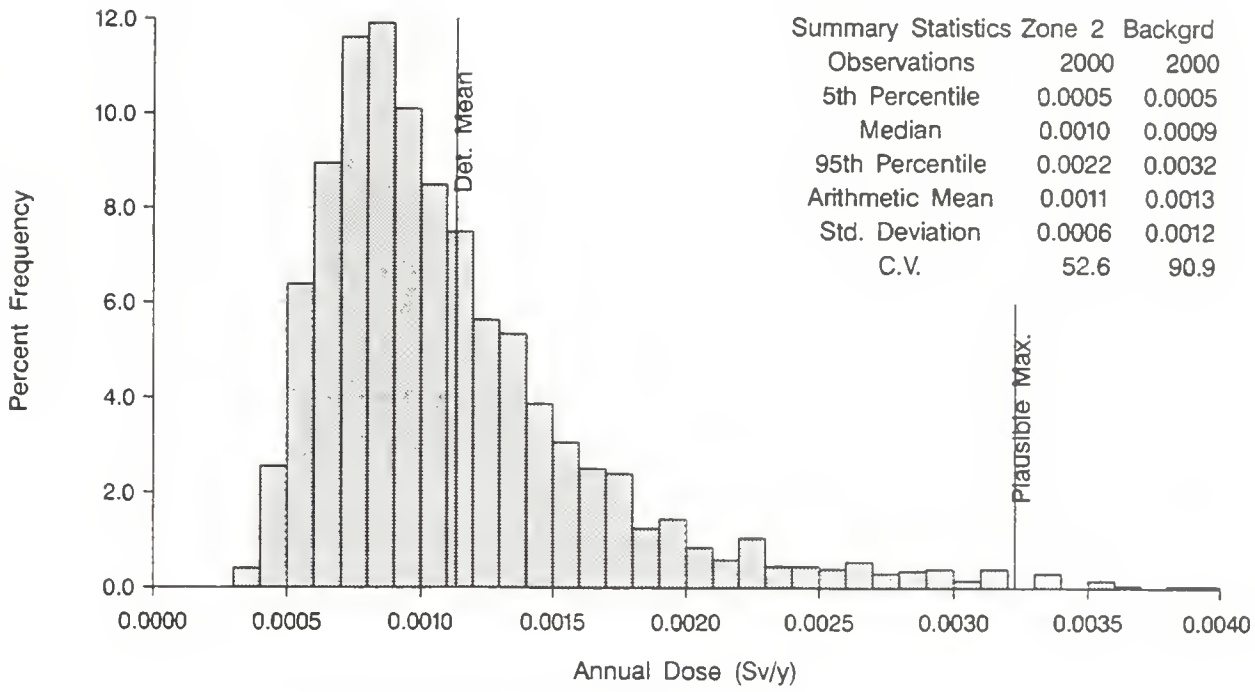


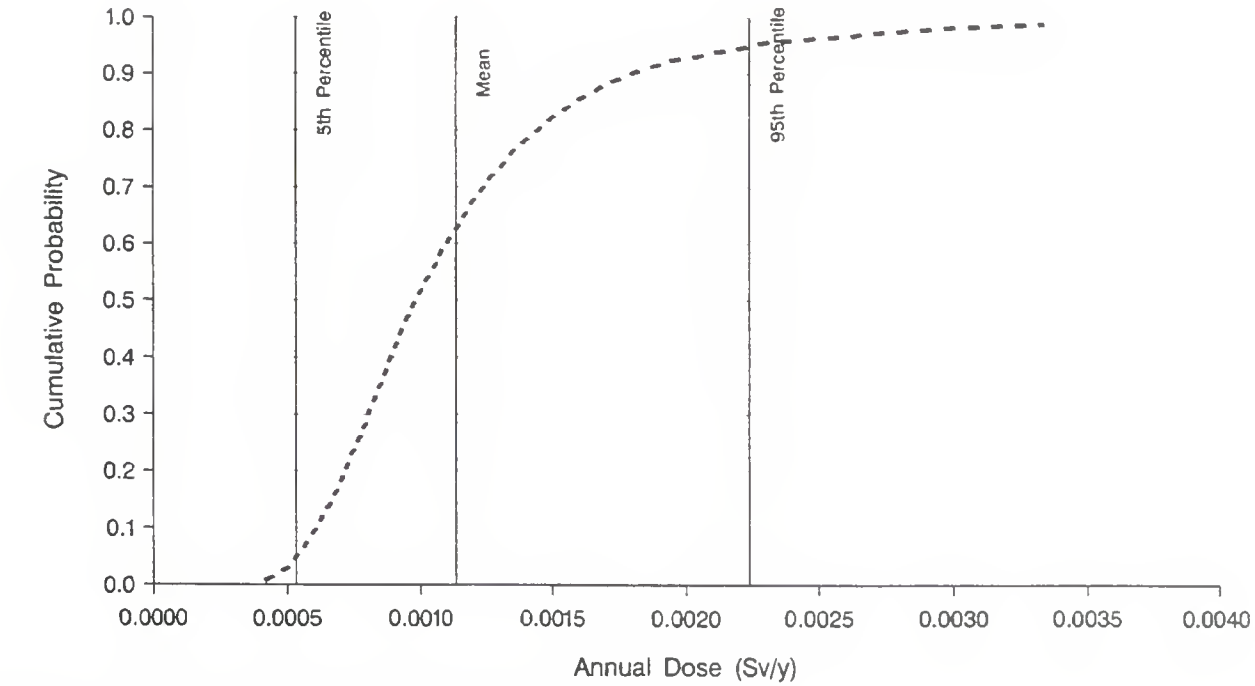


Horizontal axis was truncated at 99th percentile and 16 obs. were not shown.

Figure B.2.17

Distribution of Annual Dose (Sv/y) for 5 Year Old from All Radiological Sources in Zone 2

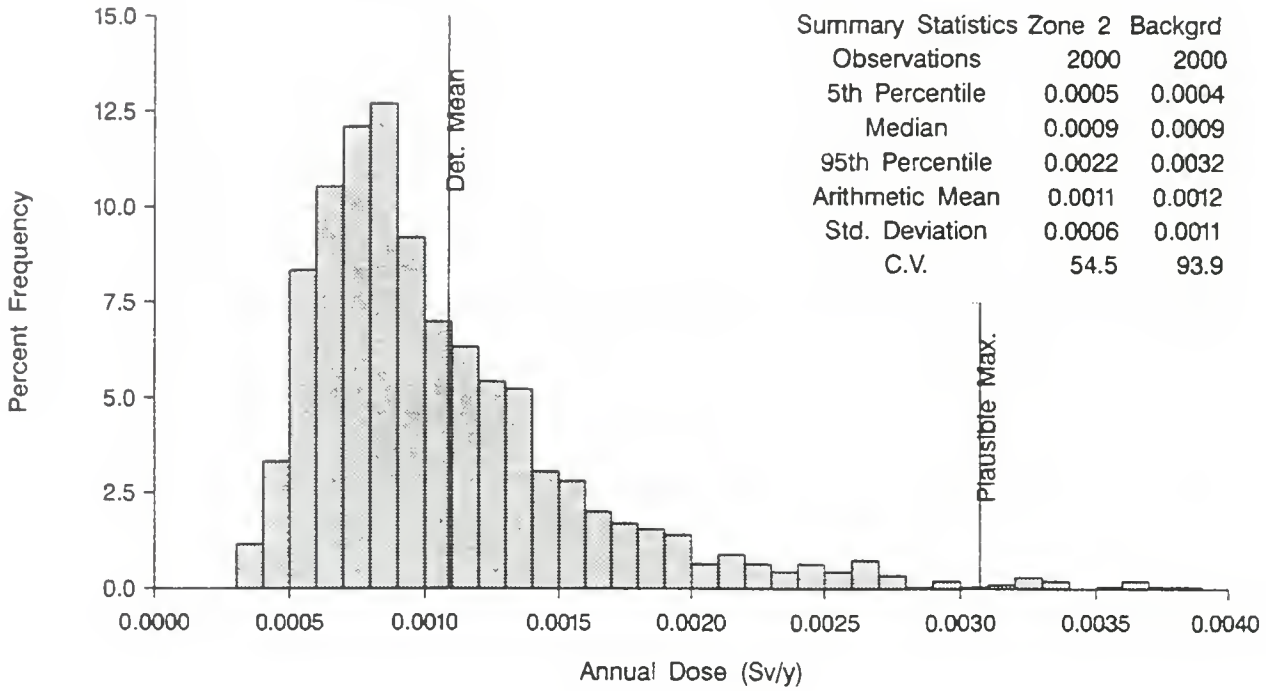


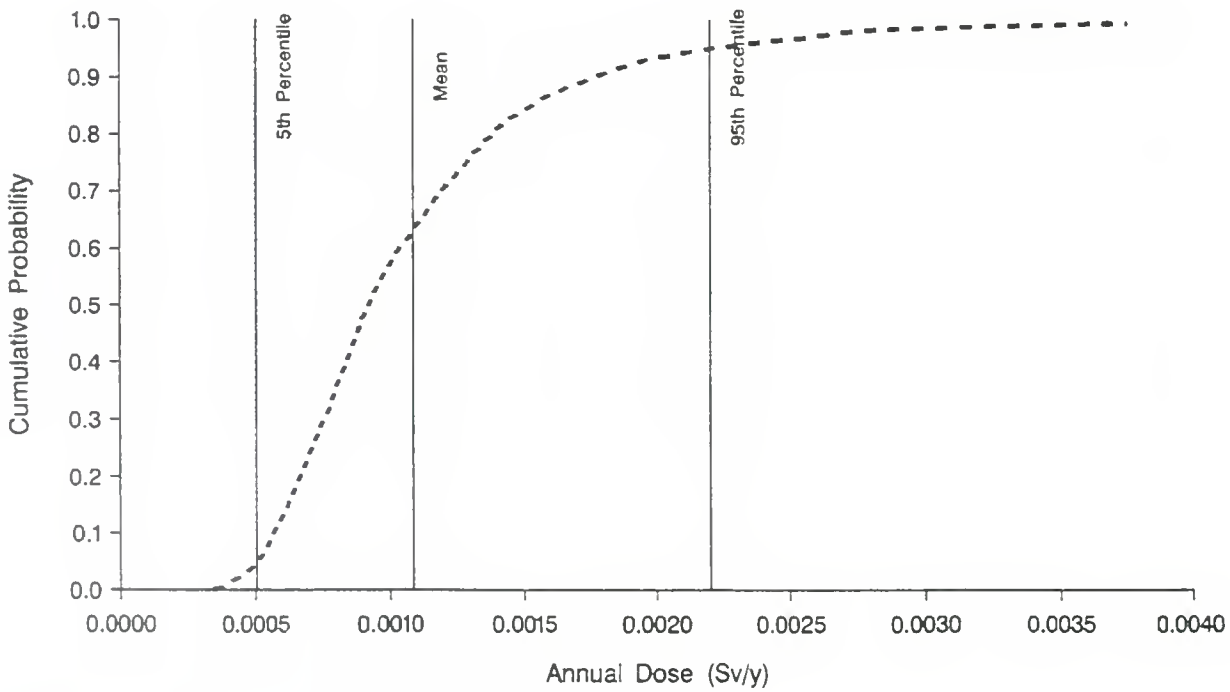


Horizontal axis was truncated at 99th percentile and 10 obs. were not shown.

Figure B.2.18

Distribution of Annual Dose (Sv/y) for 10 Year Old from All Radiological Sources in Zone 2

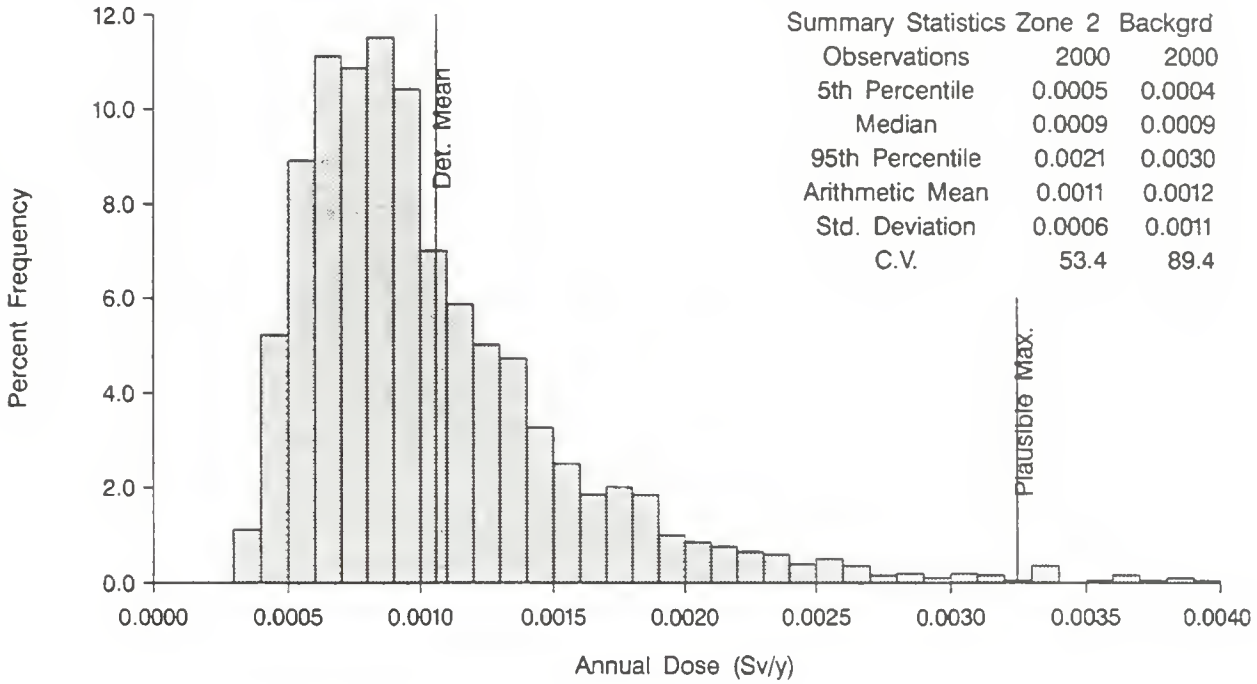


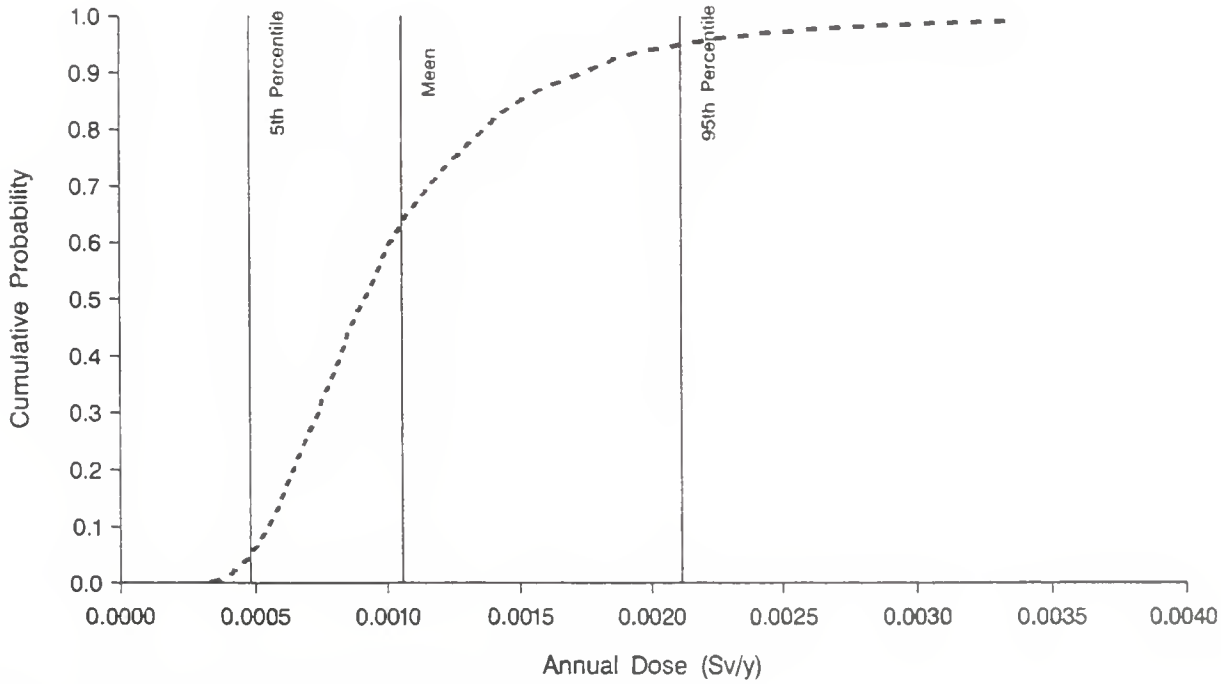


Horizontal axis was truncated at 99th percentile and 9 obs. were not shown.

Figure B.2.19

Distribution of Annual Dose (Sv/y) for 15 Year Old from All Radiological Sources in Zone 2

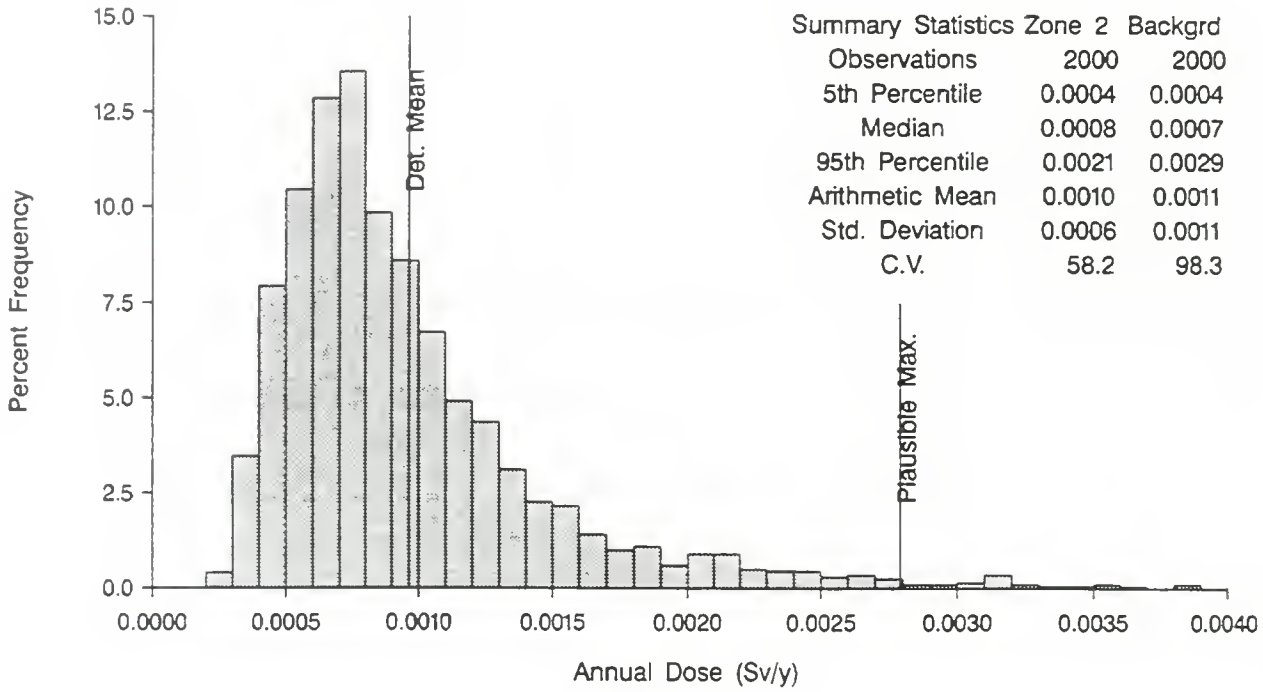


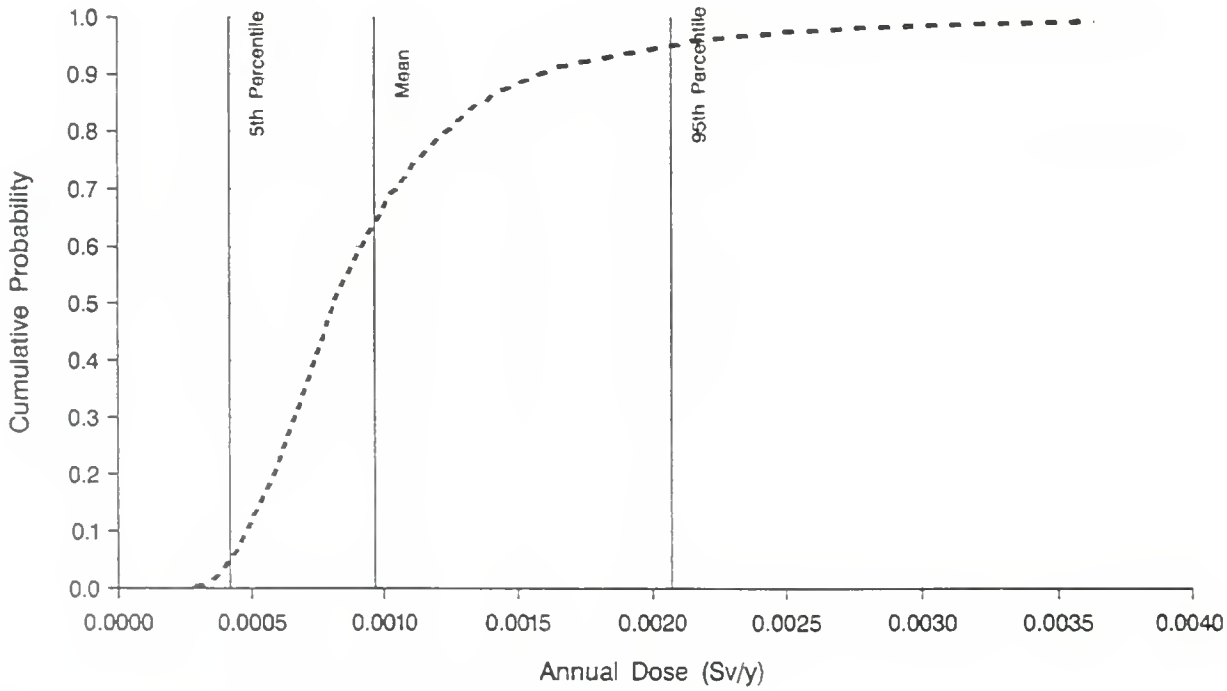


Honzontal axis was truncated at 99th percentile and 5 obs. were not shown.

Figure B.2.20

Distribution of Annual Dose (Sv/y) for Adult from All Radiological Sources in Zone 2

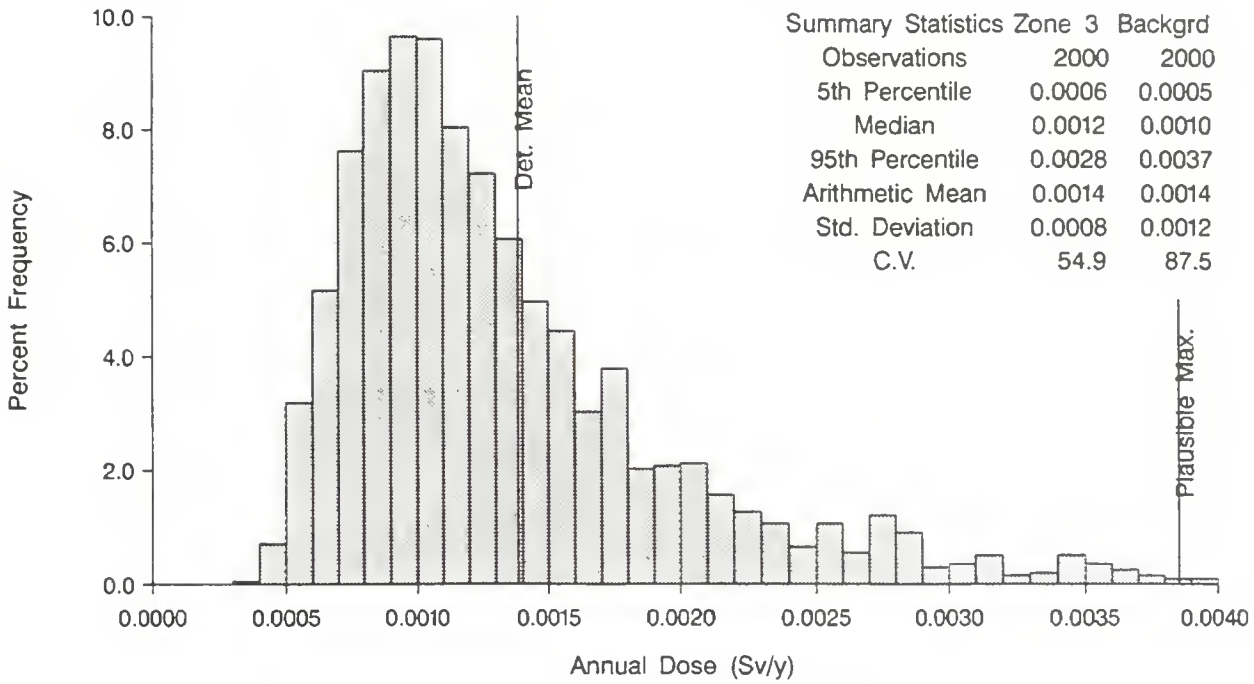


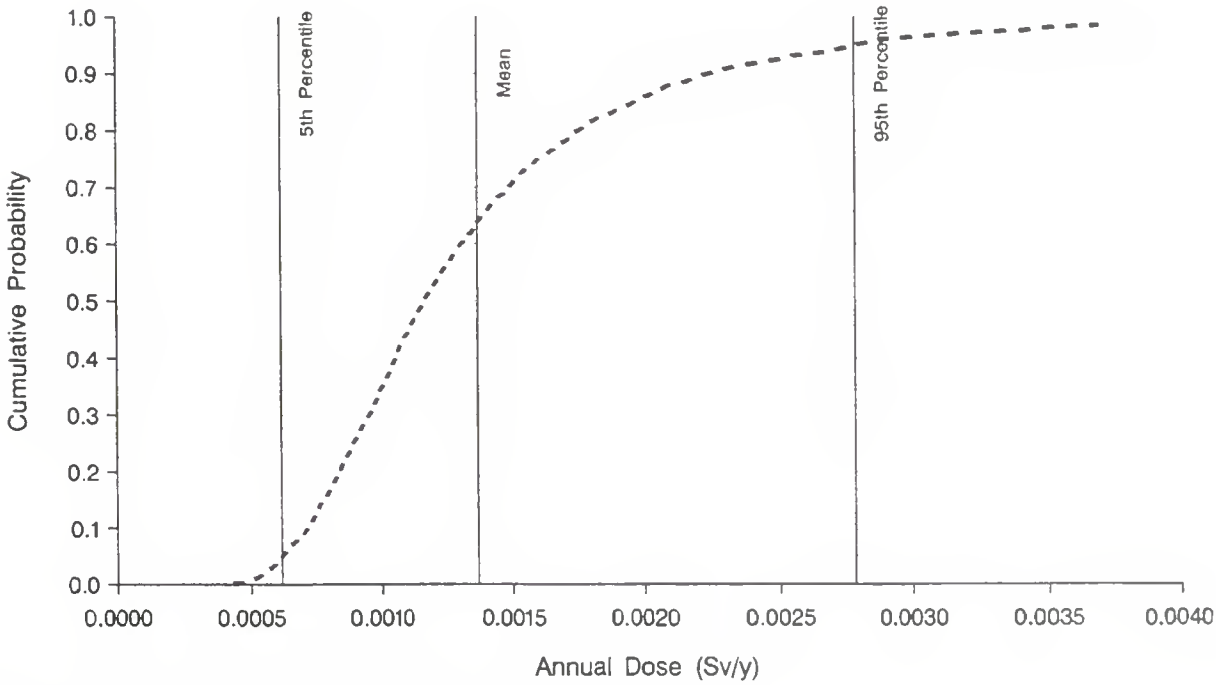


Horizontal axis was truncated at 99th percentile and 8 obs. were not shown.

Figure B.2.21

Distribution of Annual Dose (Sv/y) for 1 Year Old from All Radiological Sources in Zone 3

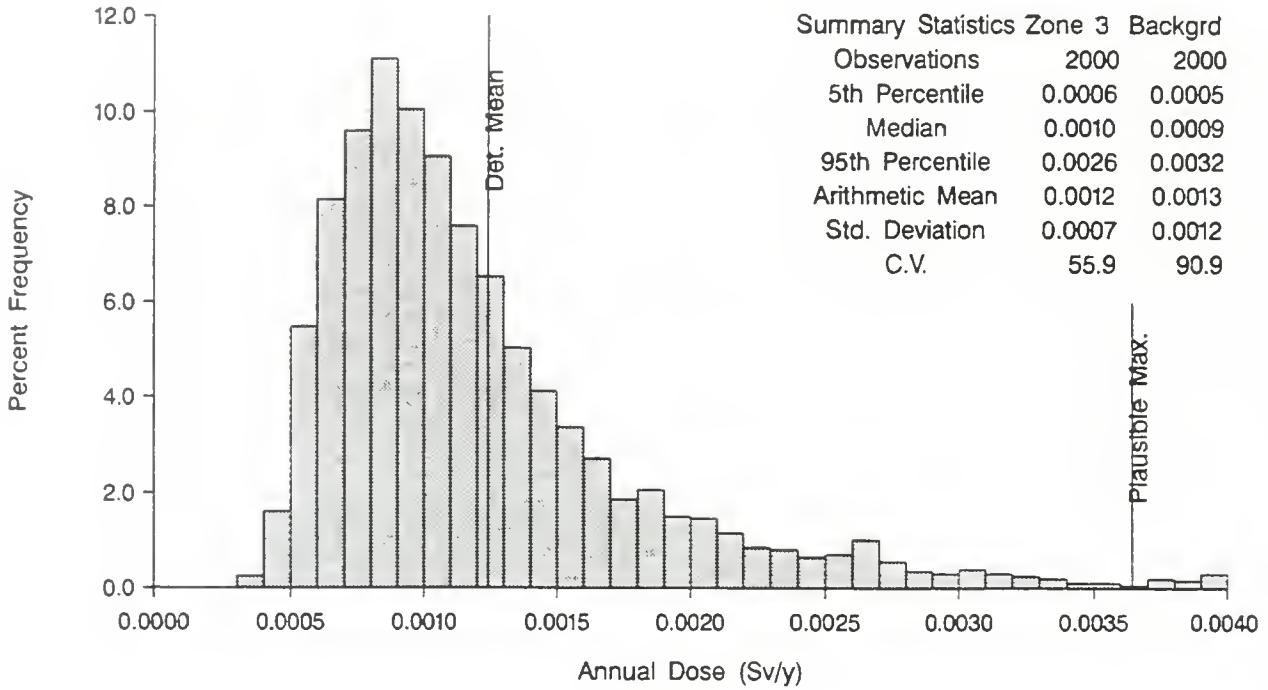


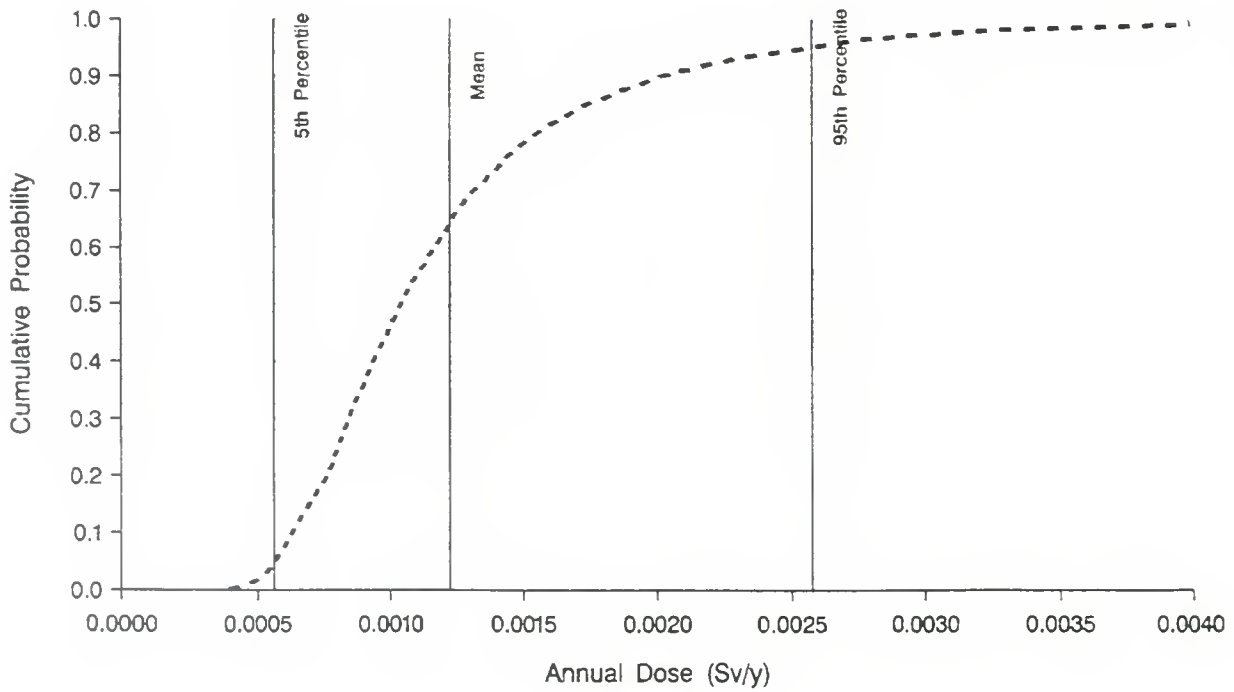


Horizontal axis was truncated at 99th percentile and 20 obs. were not shown.

Figure B.2.22

Distribution of Annual Dose (Sv/y) for 5 Year Old from All Radiological Sources in Zone 3

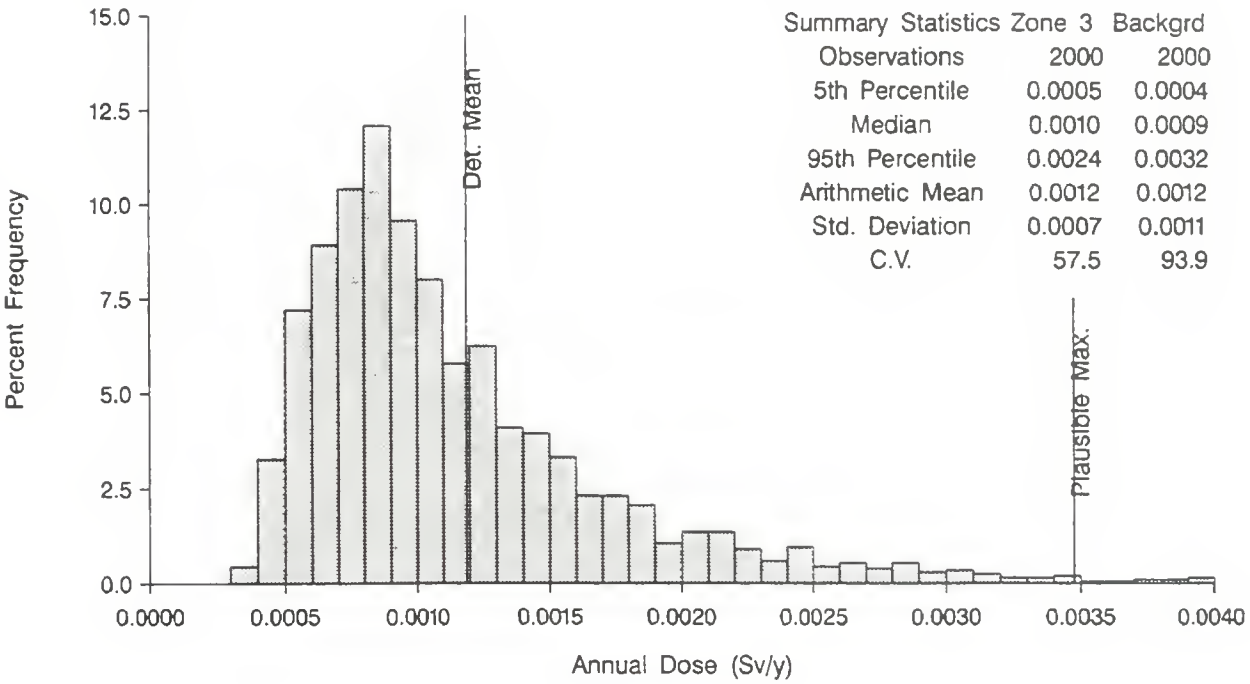


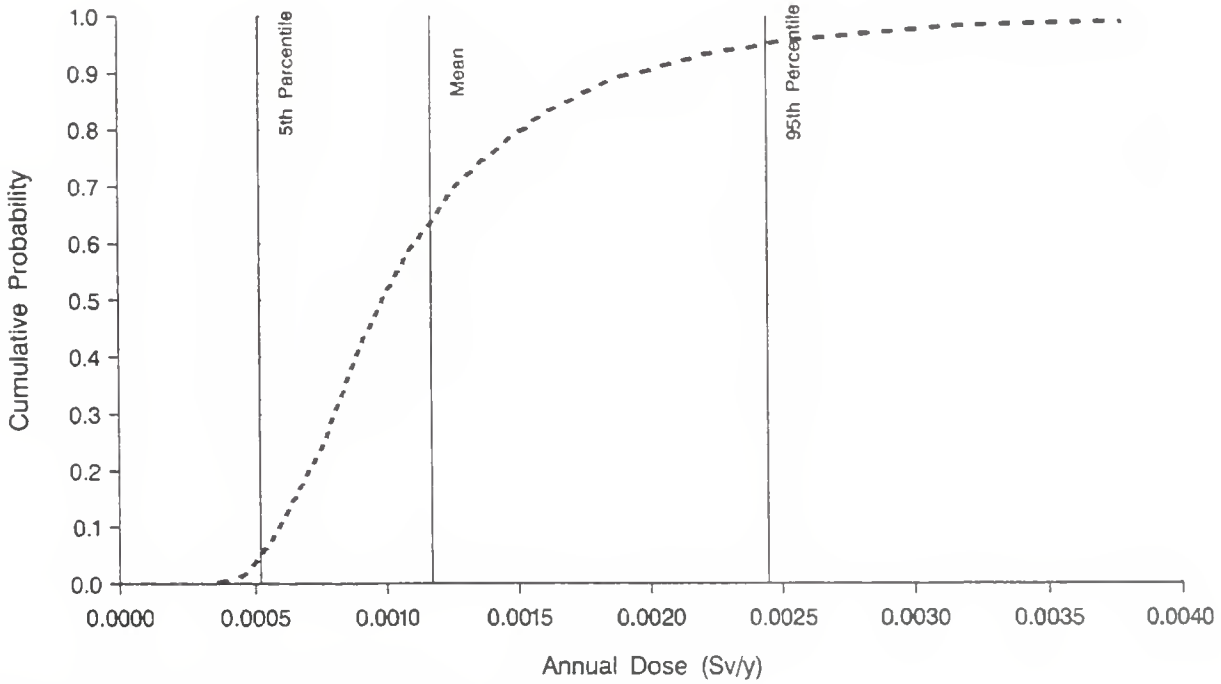


Honzontal axis was truncated at 99th percentile and 11 obs. were not shown.

Figure B.2.23

Distribution of Annual Dose (Sv/y) for 10 Year Old from All Radiological Sources in Zone 3

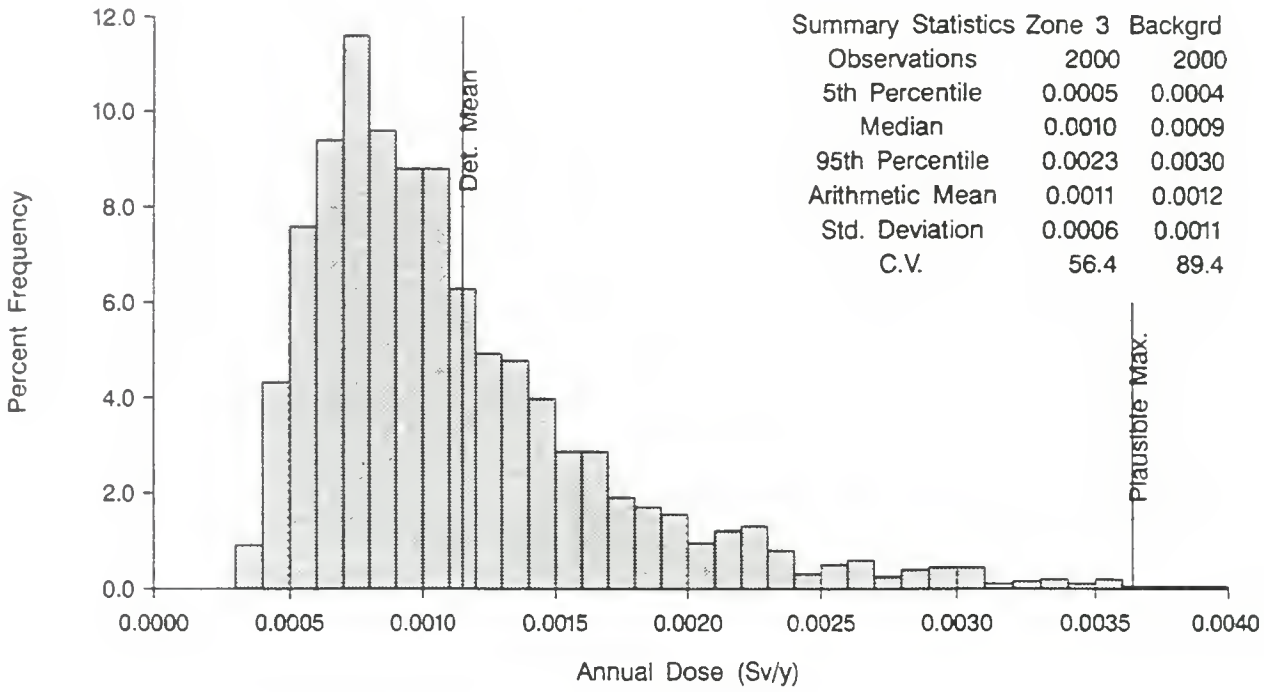


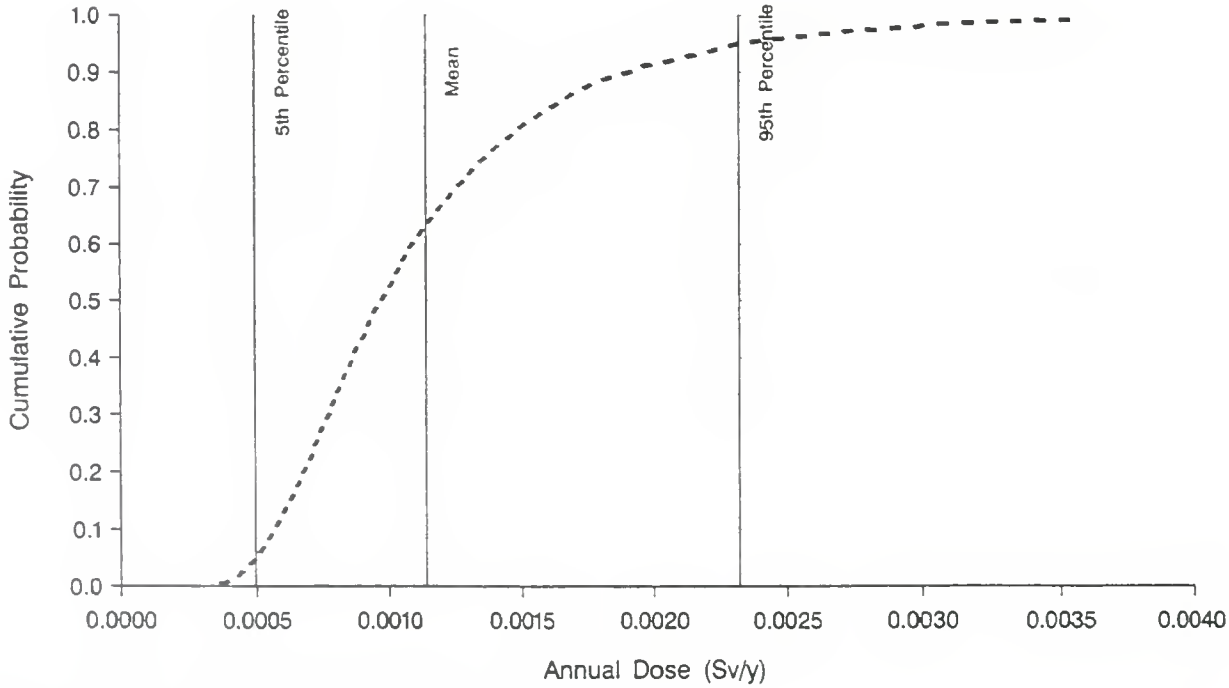


Horizontal axis was truncated at 99th percentile and 13 obs. were not shown.

Figure B.2.24

Distribution of Annual Dose (Sv/y) for 15 Year Old from All Radiological Sources in Zone 3

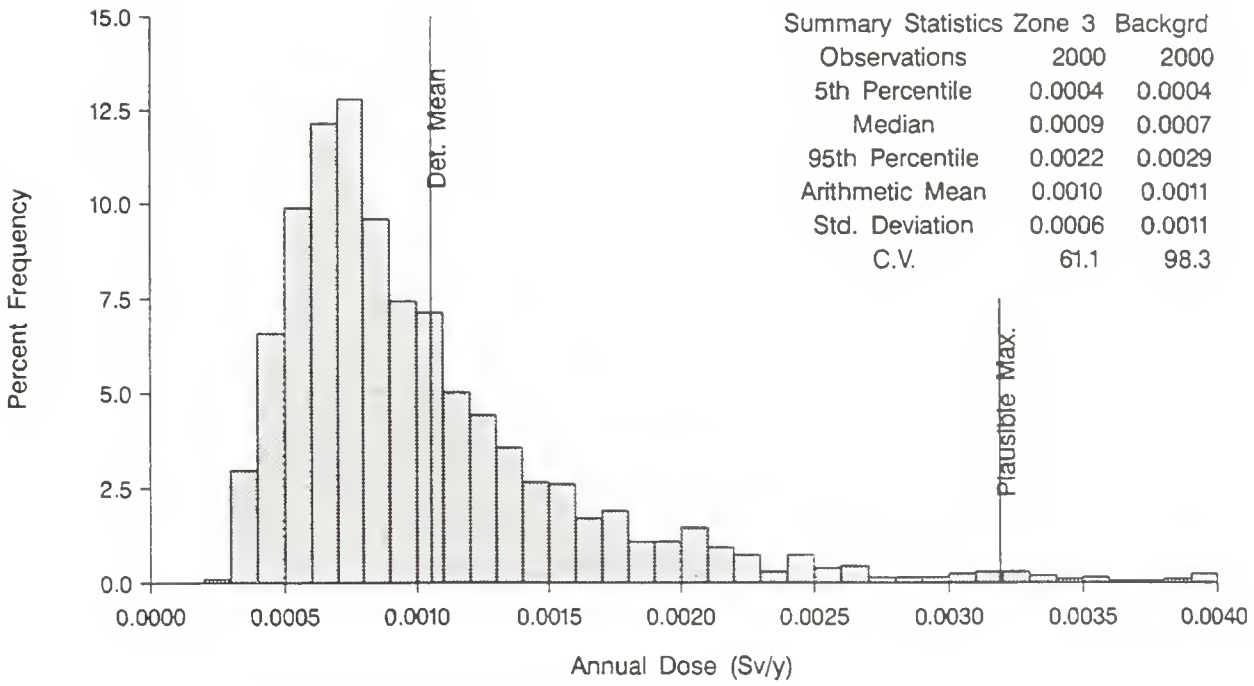


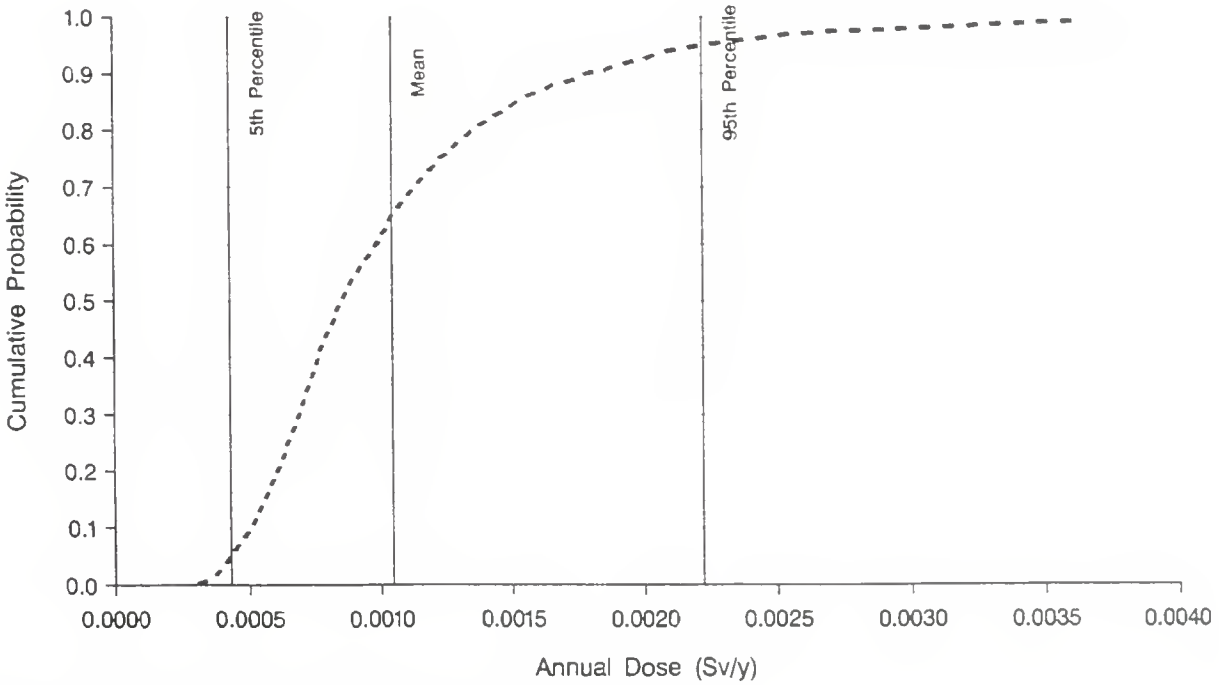


Horizontal axis was truncated at 99th percentile and 9 obs. were not shown.

Figure B.2.25

Distribution of Annual Dose (Sv/y) for Adult from All Radiological Sources in Zone 3

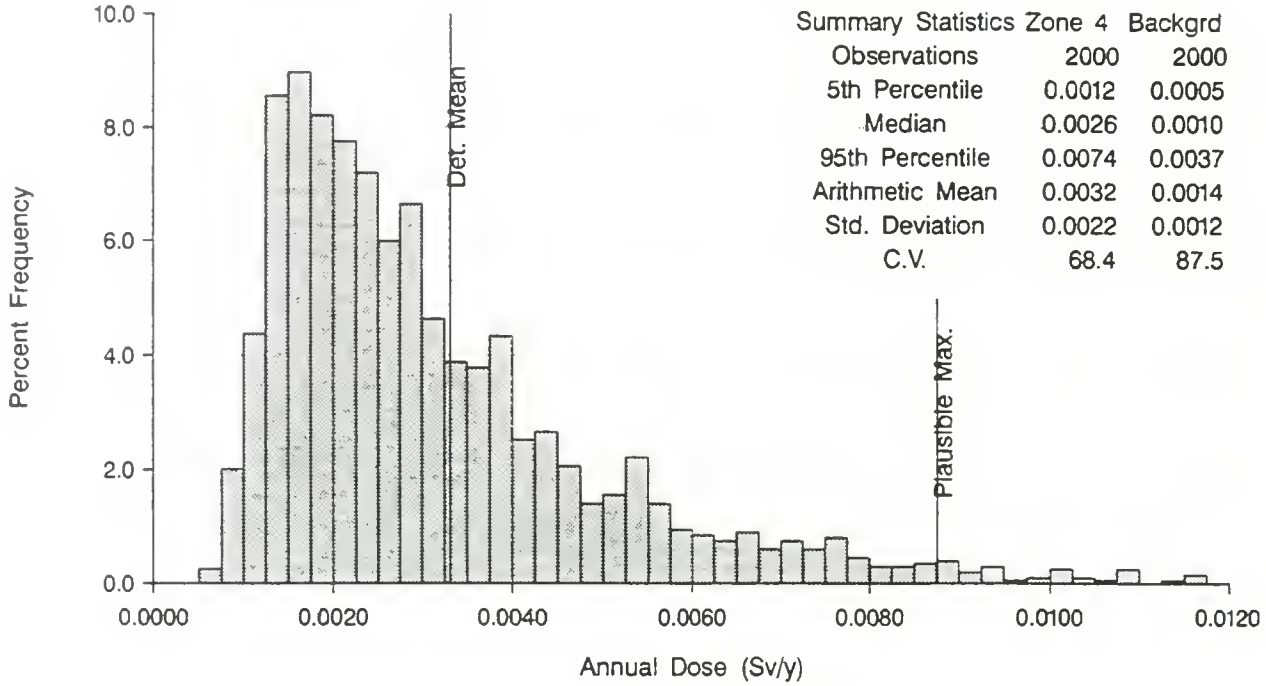


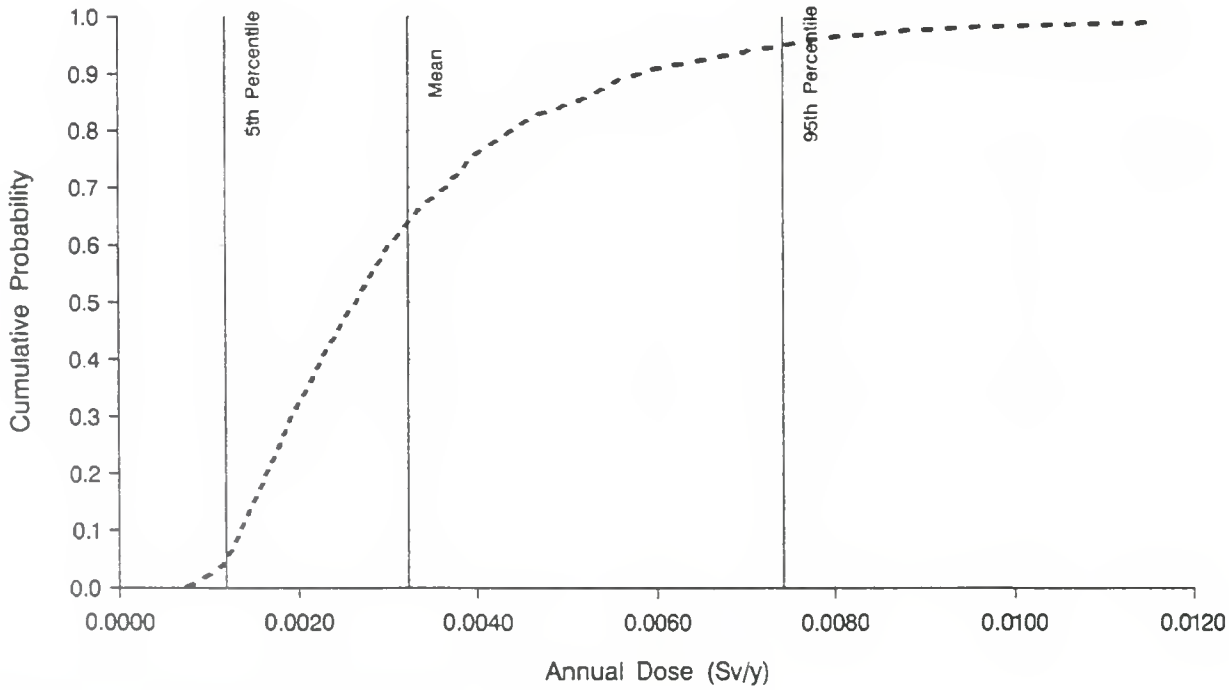


Horizontal axis was truncated at 99th percentile and 8 obs. were not shown.

Figure B.2.26

Distribution of Annual Dose (Sv/y) for 1 Year Old from All Radiological Sources in Zone 4

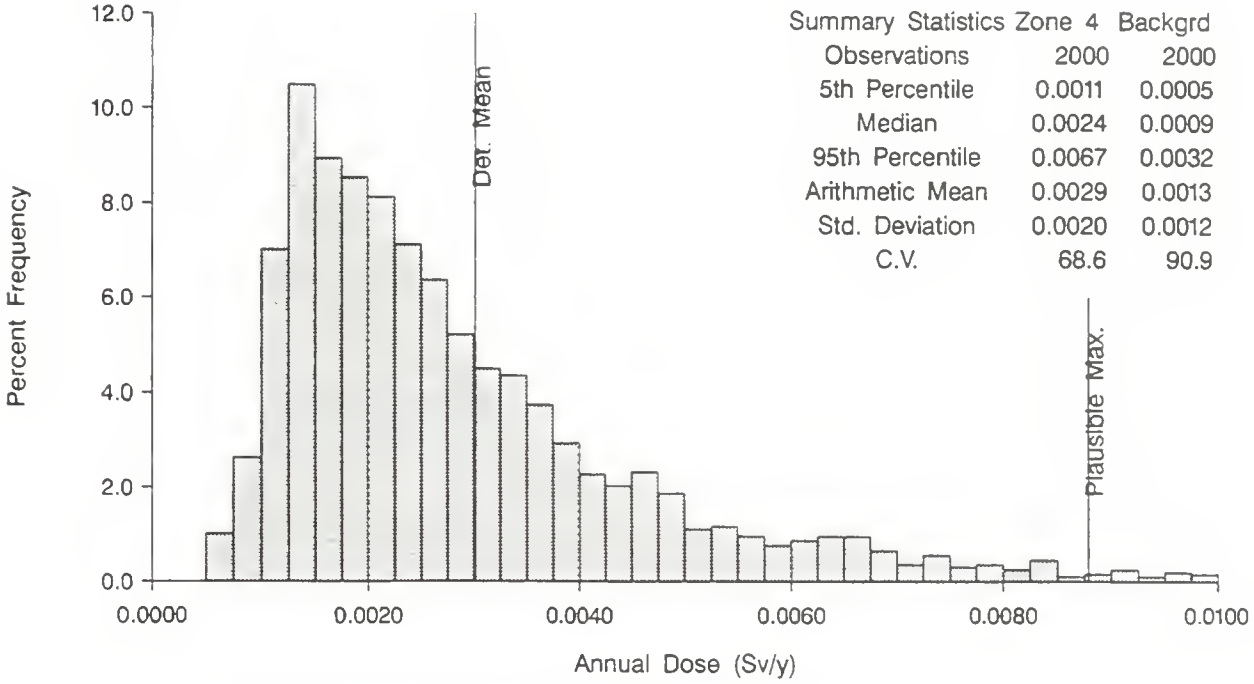


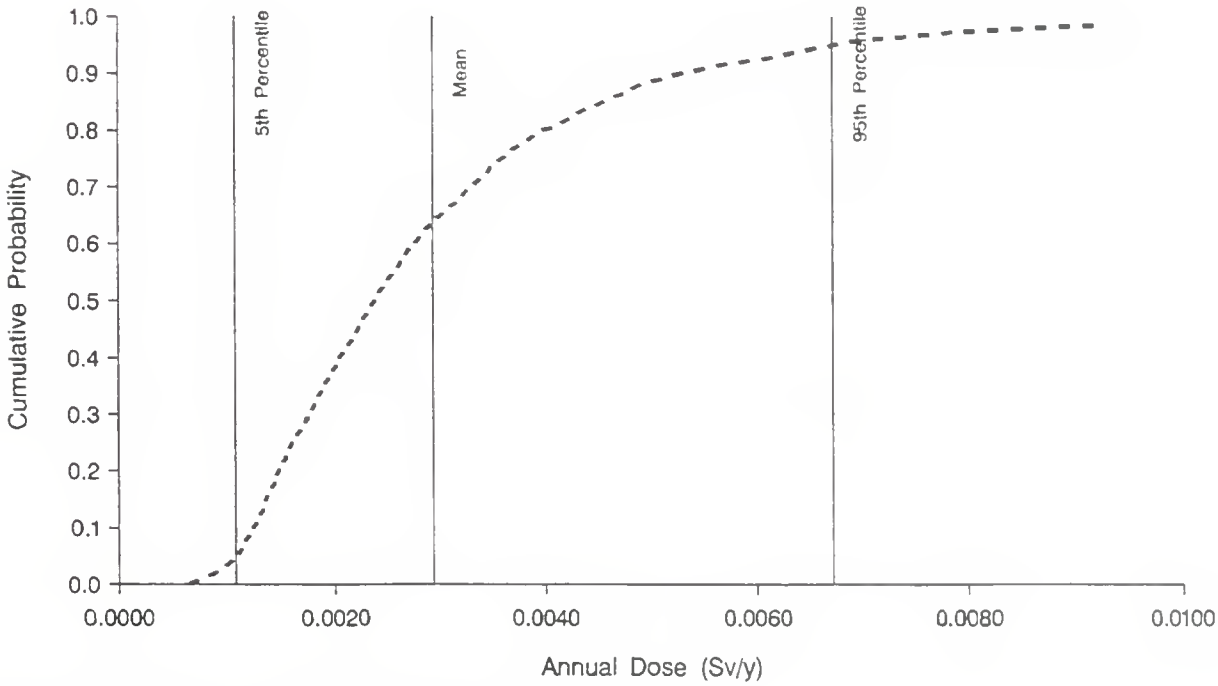


Horizontal axis was truncated at 99th percentile and 14 obs. were not shown.

Figure B.2.27

Distribution of Annual Dose (Sv/y) for 5 Year Old from All Radiological Sources in Zone 4

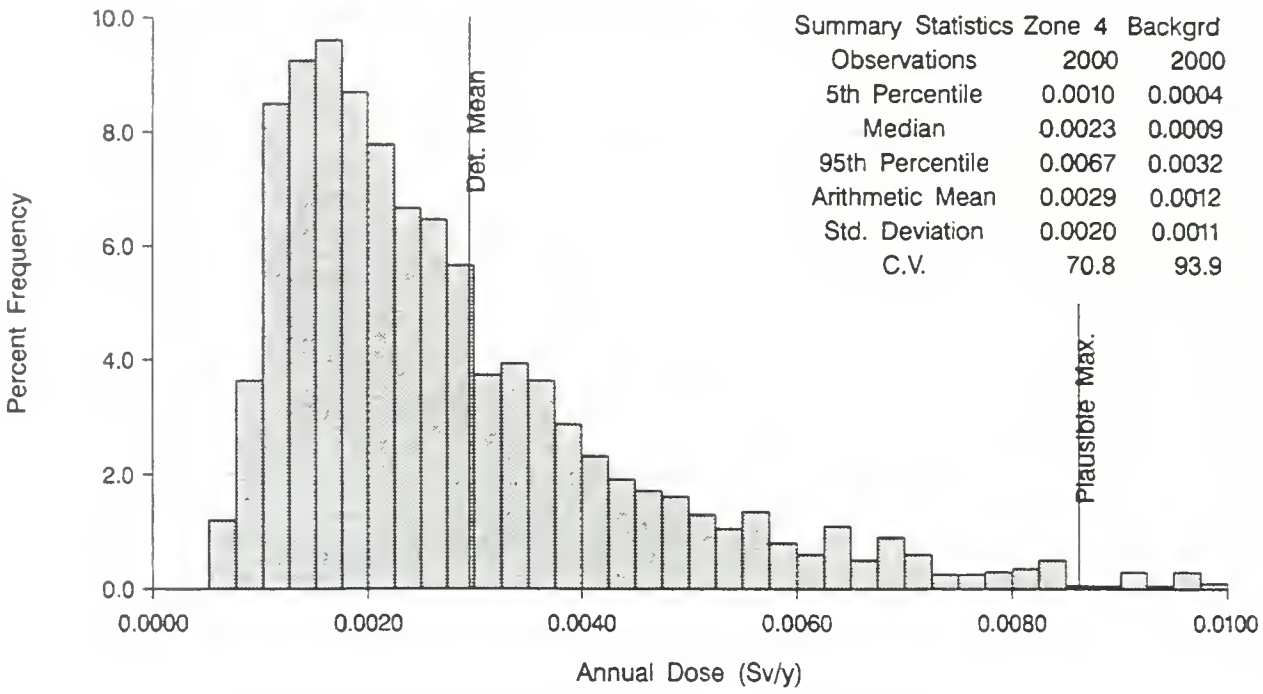


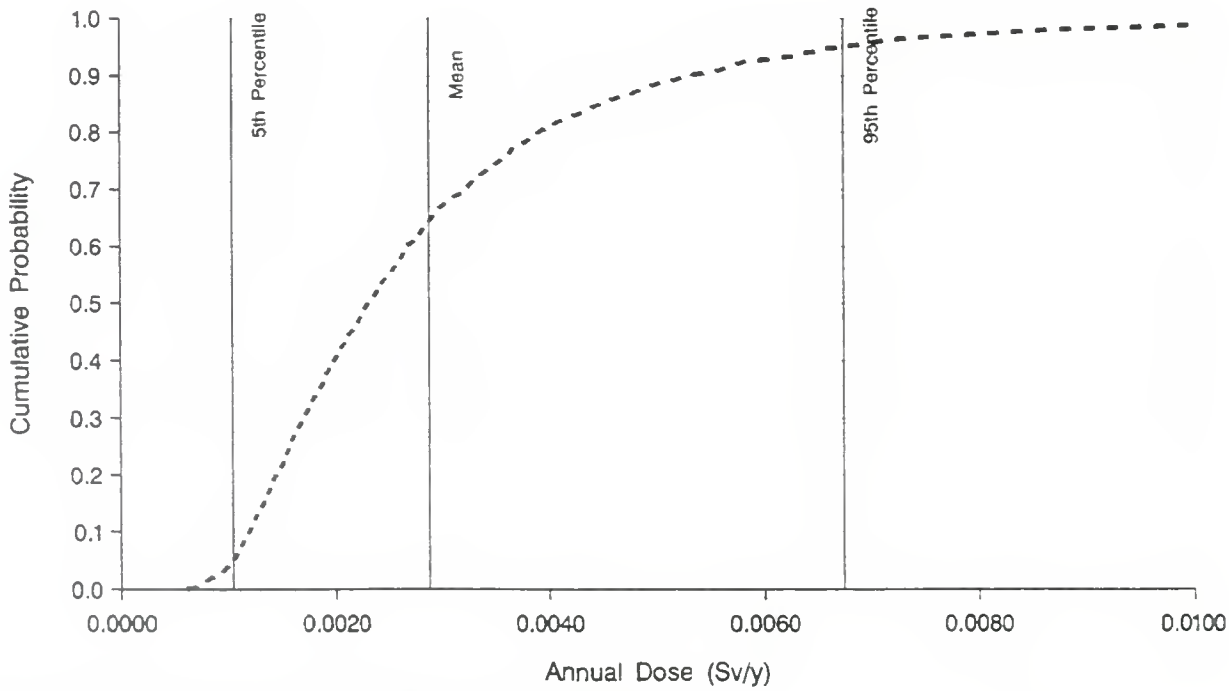


Horizontal axis was truncated at 99th percentile and 18 obs. were not shown.

Figure B.2.28

Distribution of Annual Dose (Sv/y) for 10 Year Old from All Radiological Sources in Zone 4

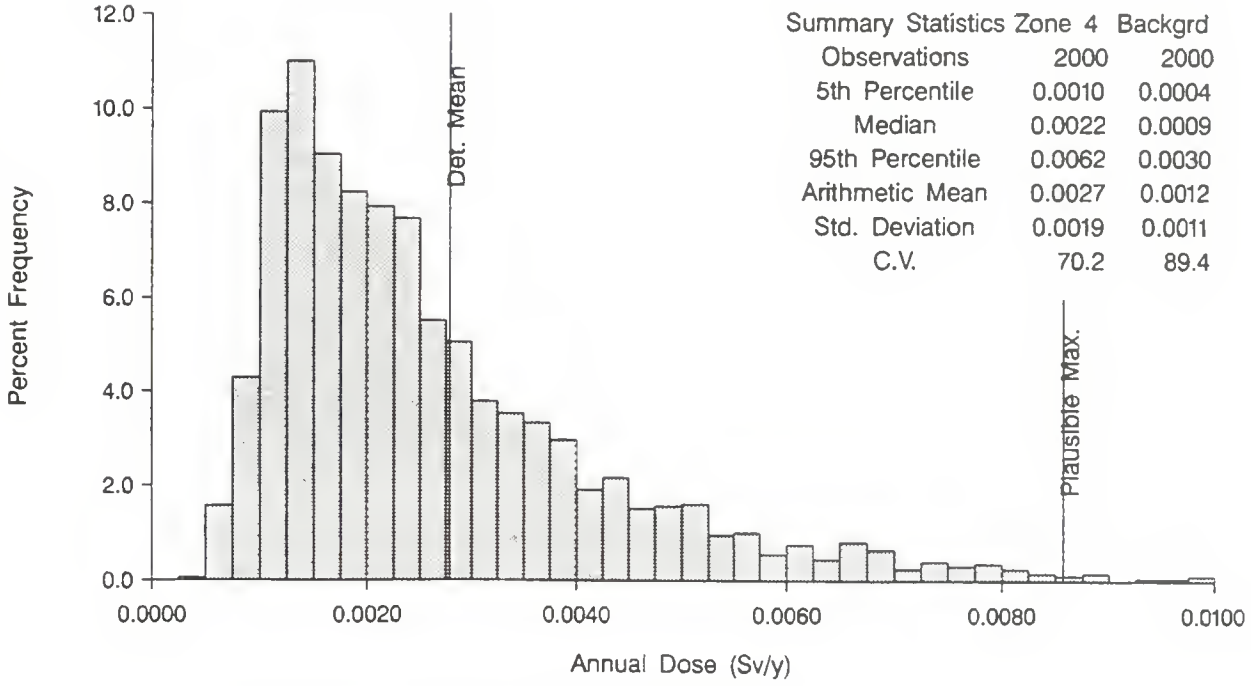


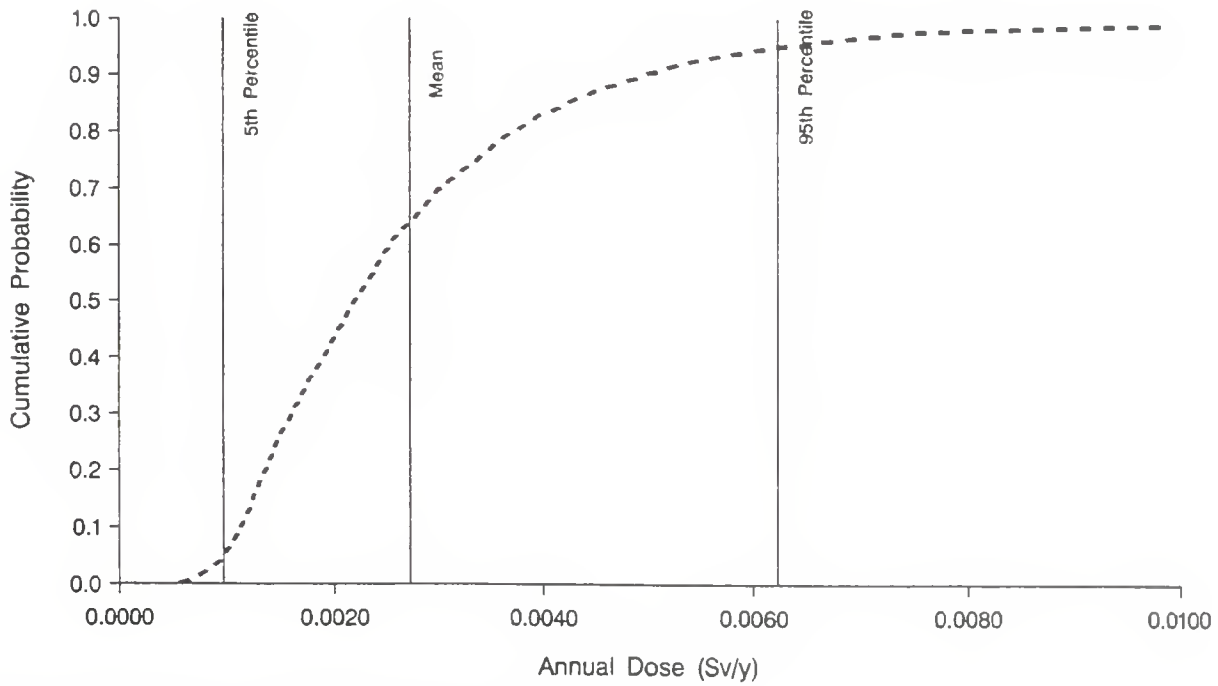


Horizontal axis was truncated at 99th percentile and 20 obs. were not shown.

Figure B.2.29

Distribution of Annual Dose (Sv/y) for 15 Year Old from All Radiological Sources in Zone 4

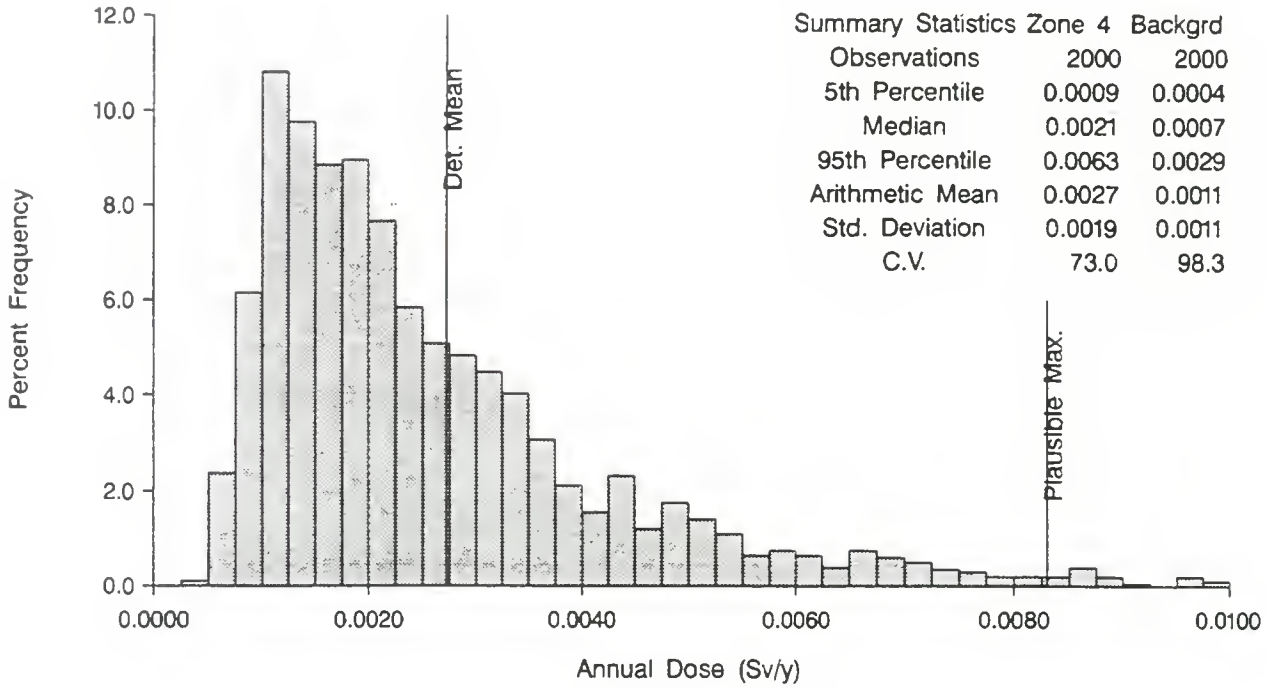


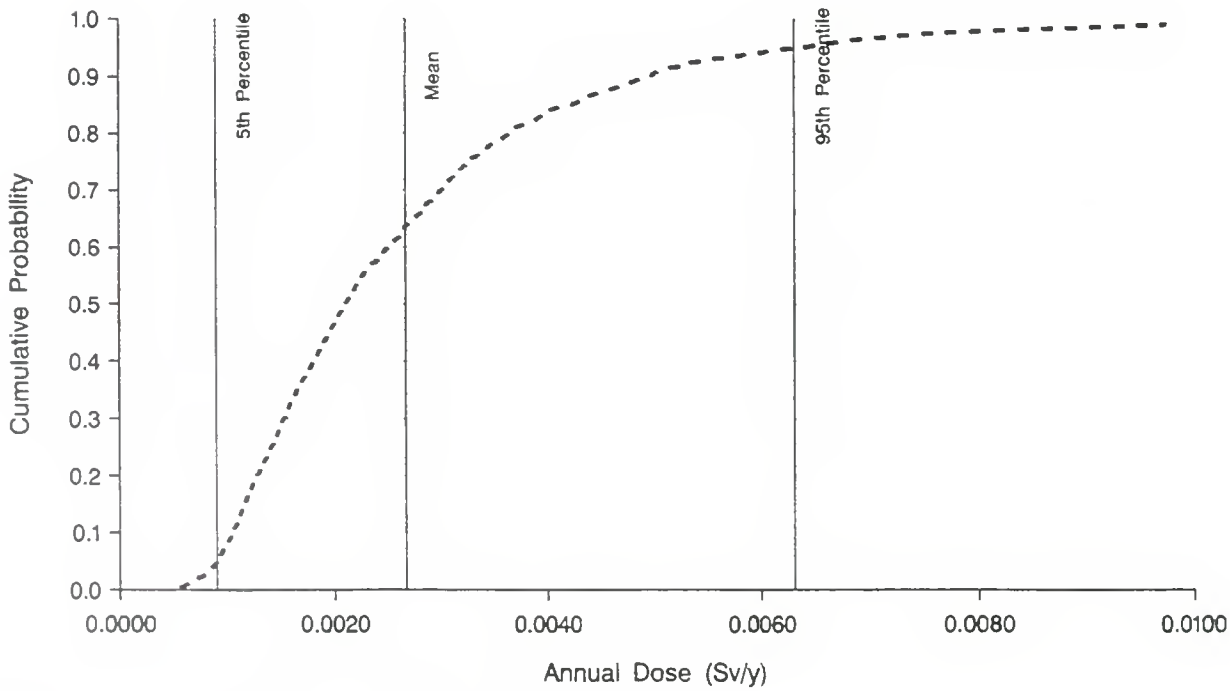


Horizontal axis was truncated at 99th percentile and 18 obs. were not shown.

Figure B.2.30

Distribution of Annual Dose (Sv/y) for Adult from All Radiological Sources in Zone 4

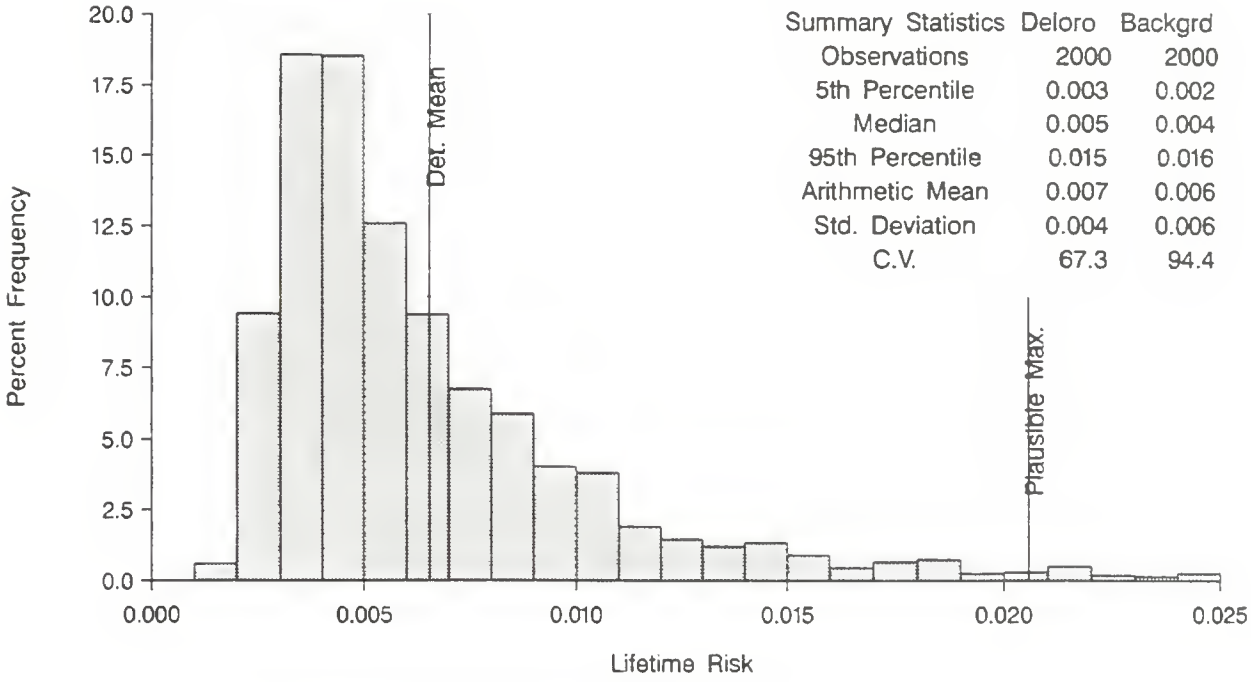


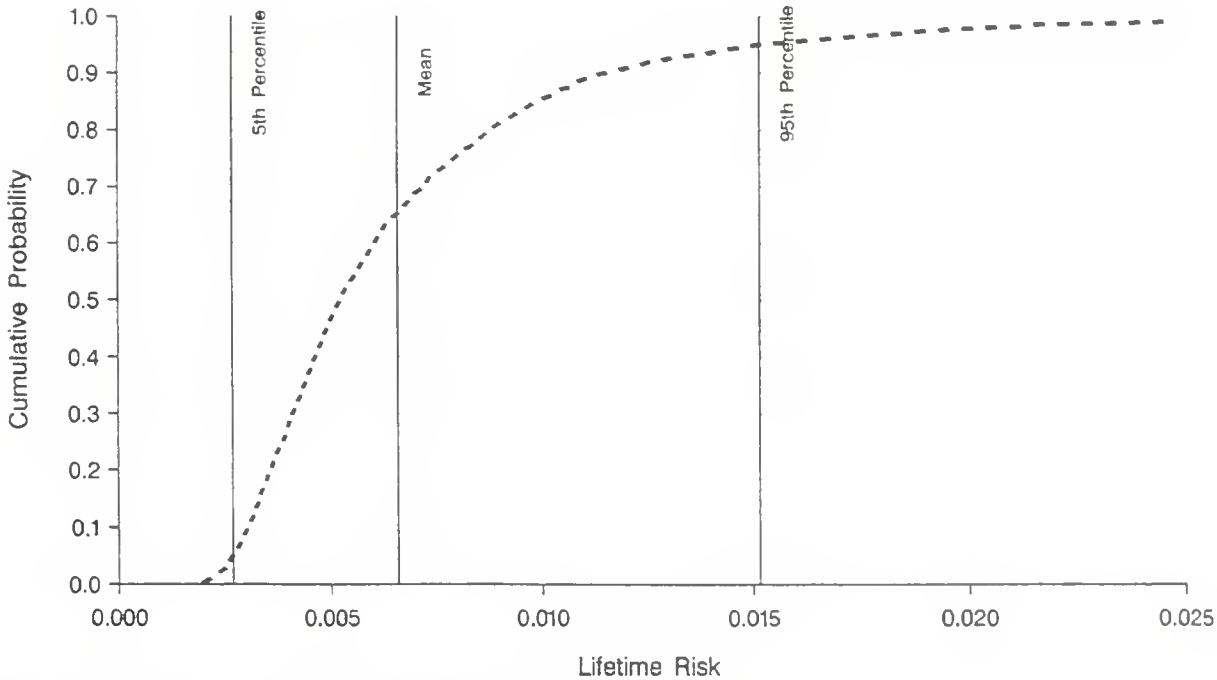


Horizontal axis was truncated at 99th percentile and 13 obs. were not shown.

Figure B.2.31

Distribution of Lifetime Risk for All Age Groups from All Radiological Sources in Deloro

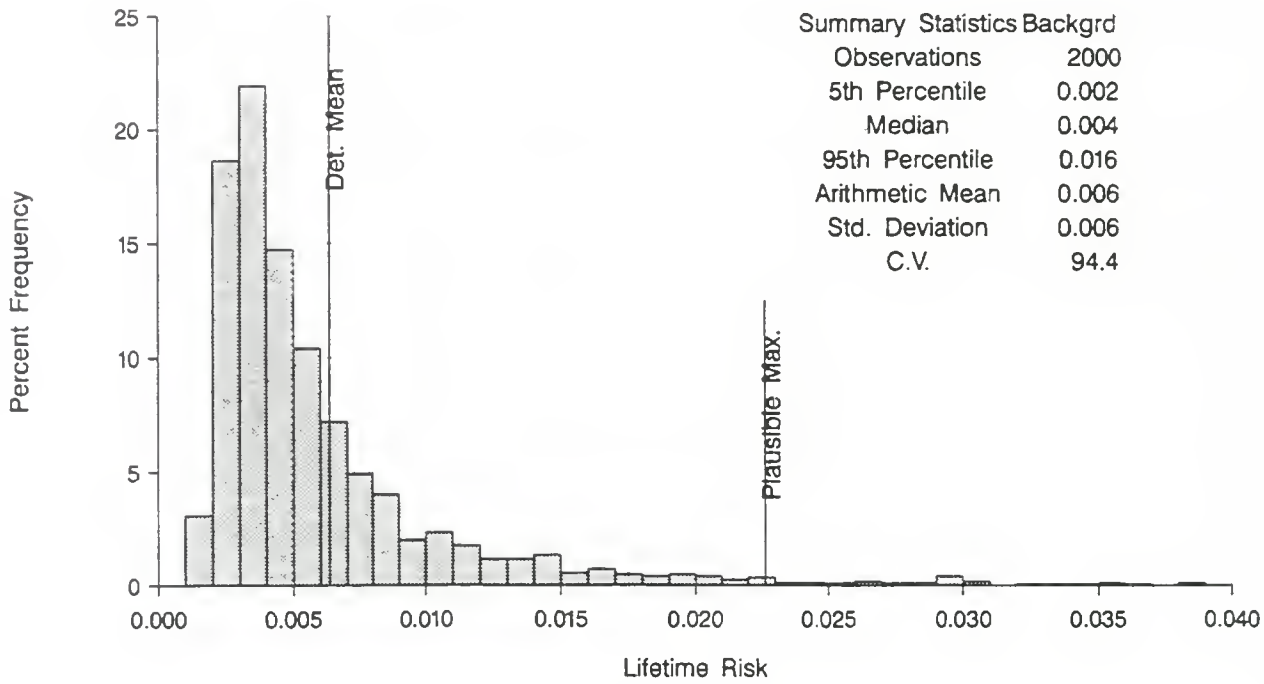


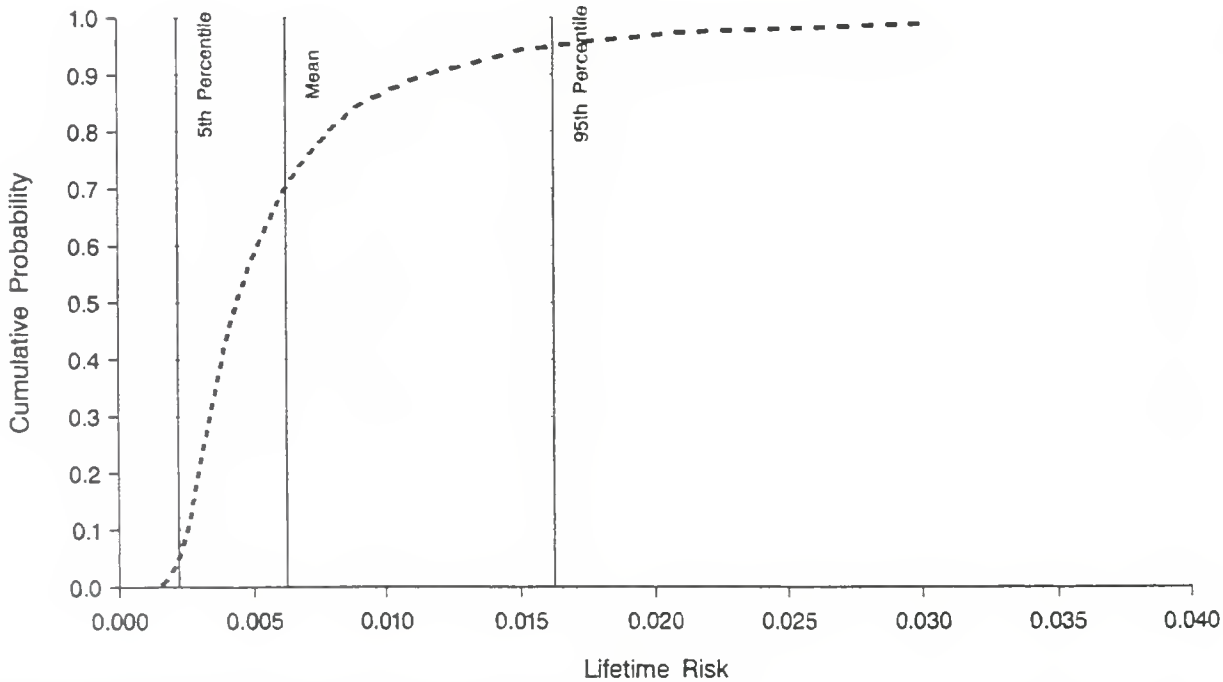


Horizontal axis was truncated at 99th percentile and 15 obs. were not shown.

Figure B.2.32

Distribution of Lifetime Risk for All Age Groups from All Radiological Sources in Background

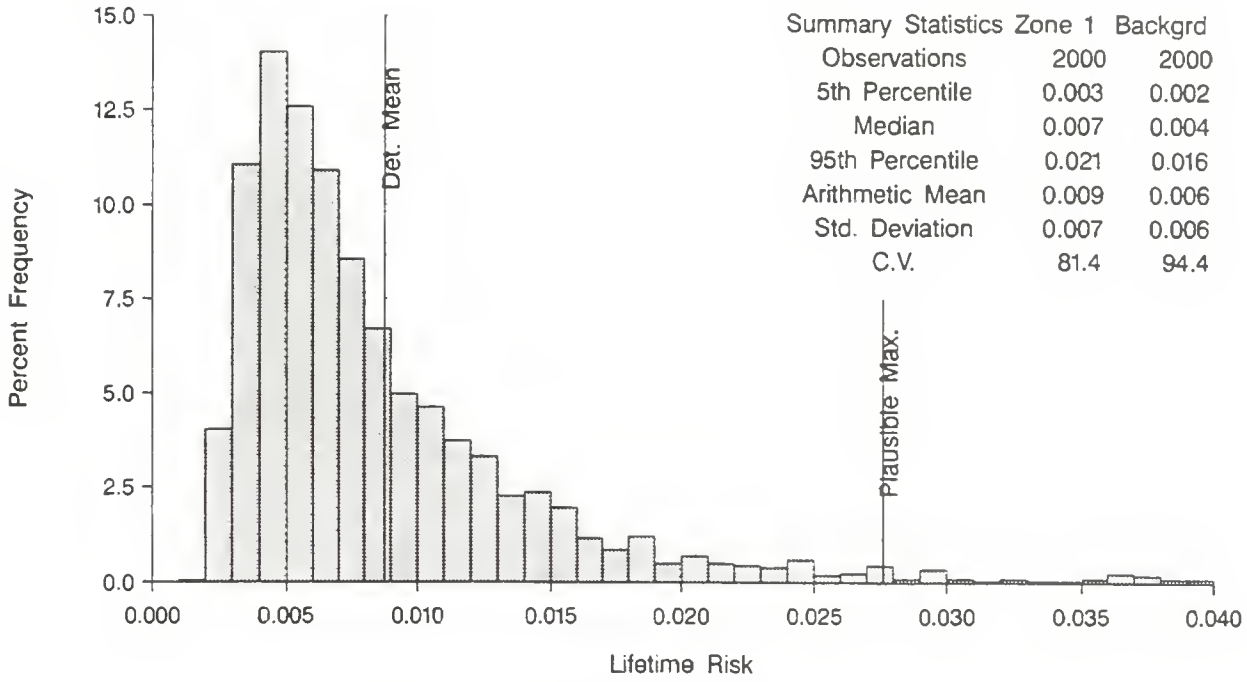


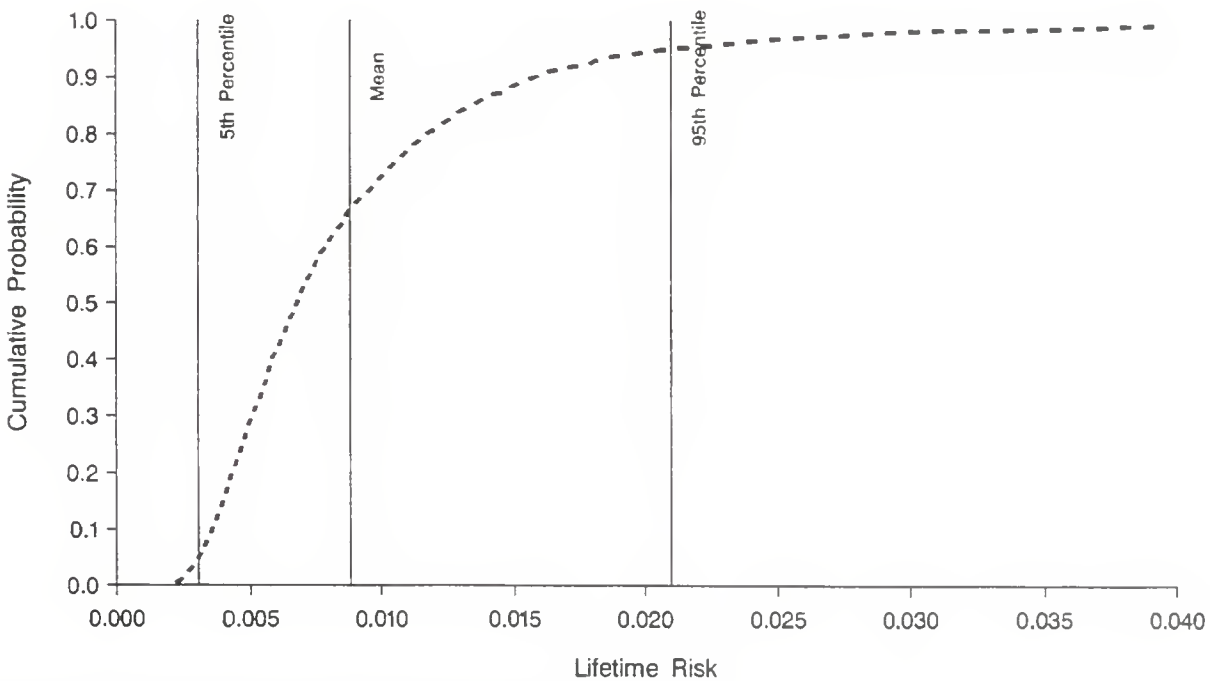


Horizontal axis was truncated at 99th percentile and 10 obs. were not shown.

Figure B.2.33

Distribution of Lifetime Risk for All Age Groups from All Radiological Sources in Zone 1

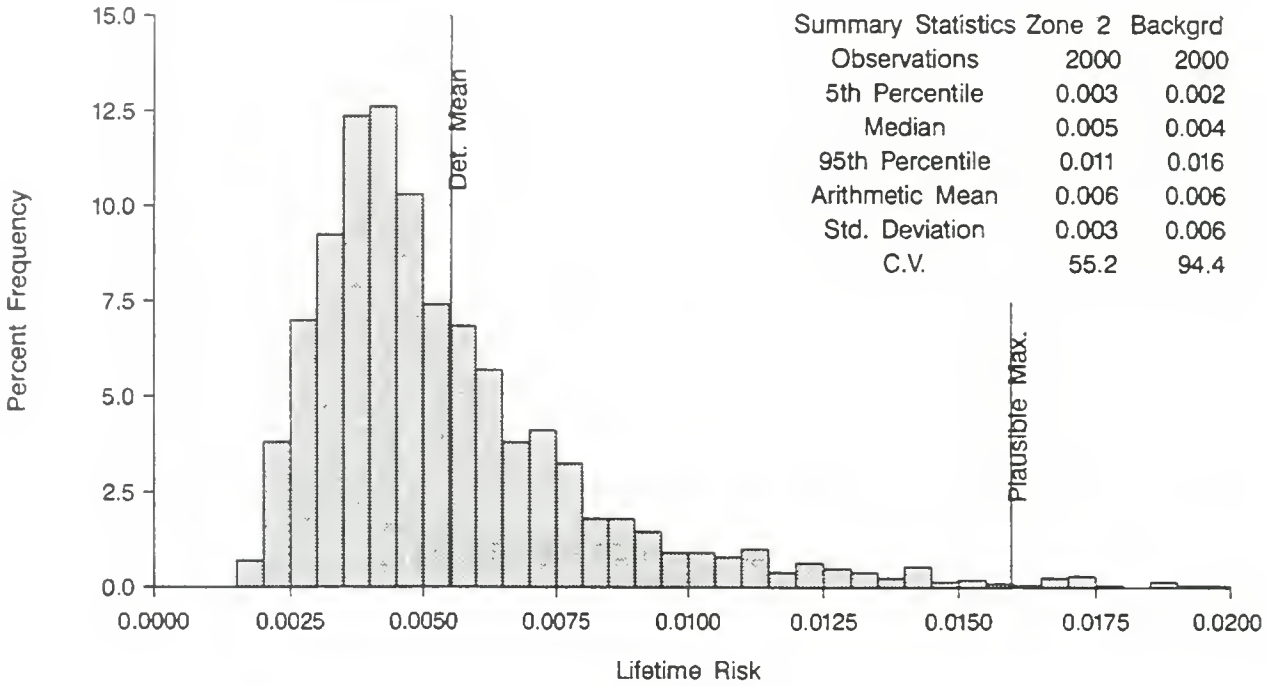


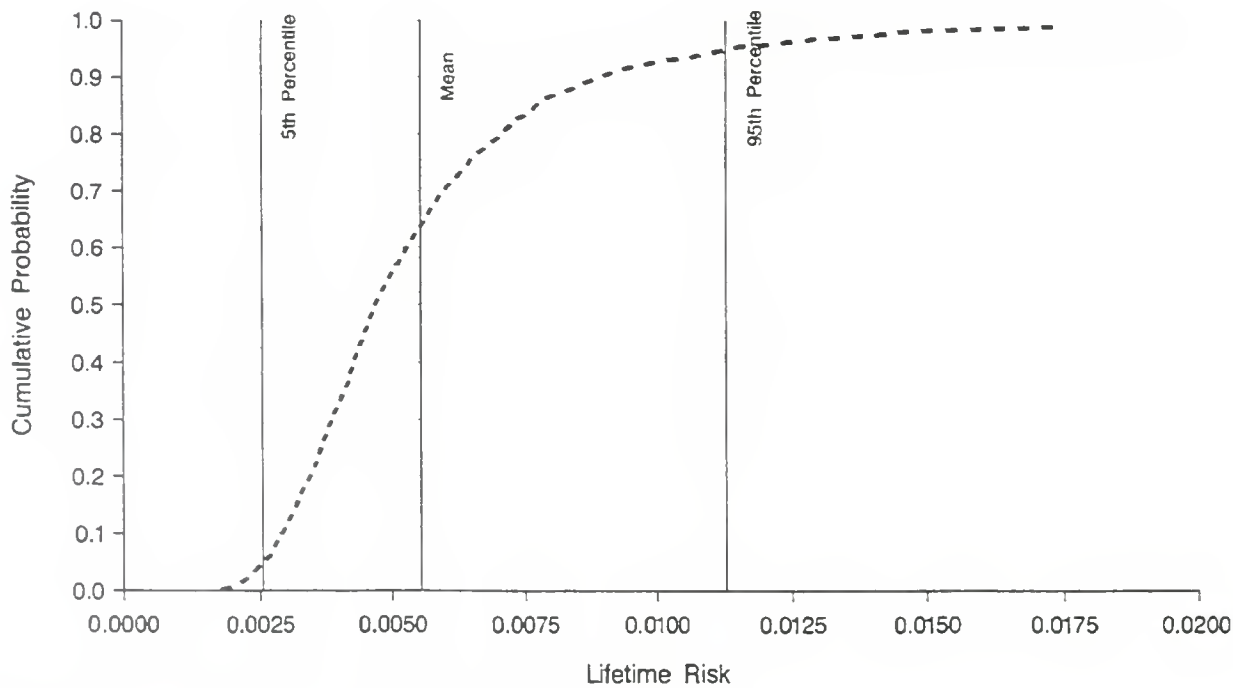


Horizontal axis was truncated at 99th percentile and 12 obs. were not shown.

Figure B.2.34

Distribution of Lifetime Risk for All Age Groups from All Radiological Sources in Zone 2

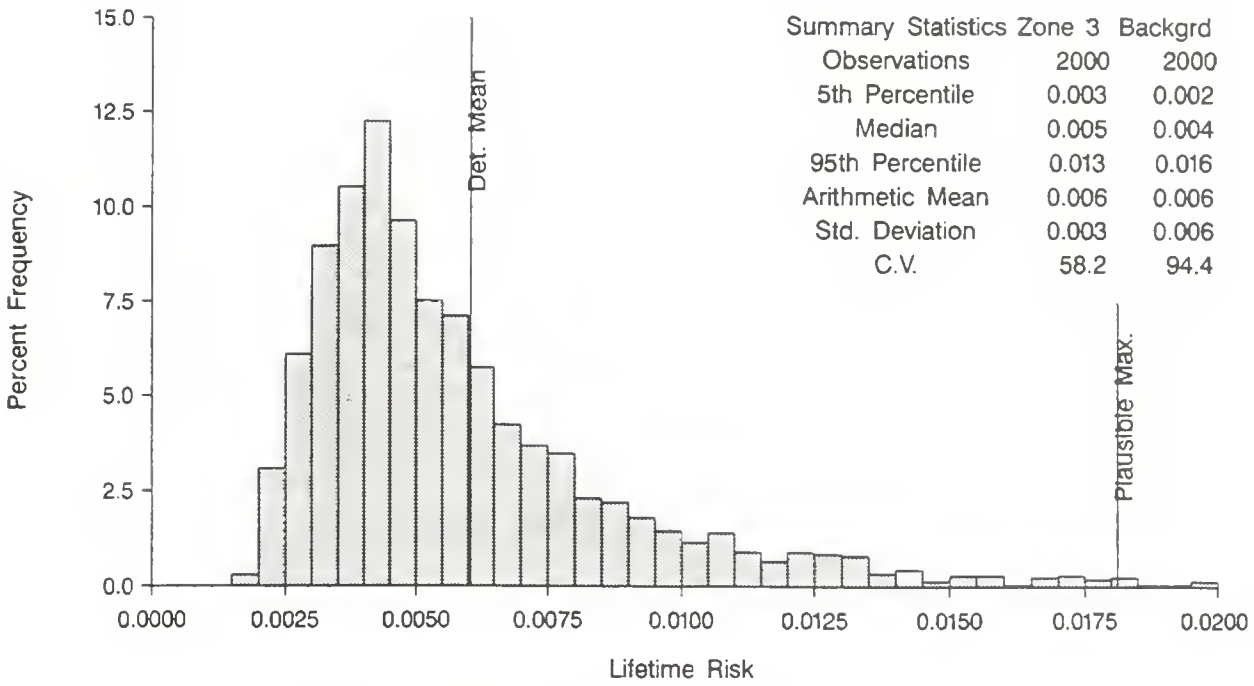


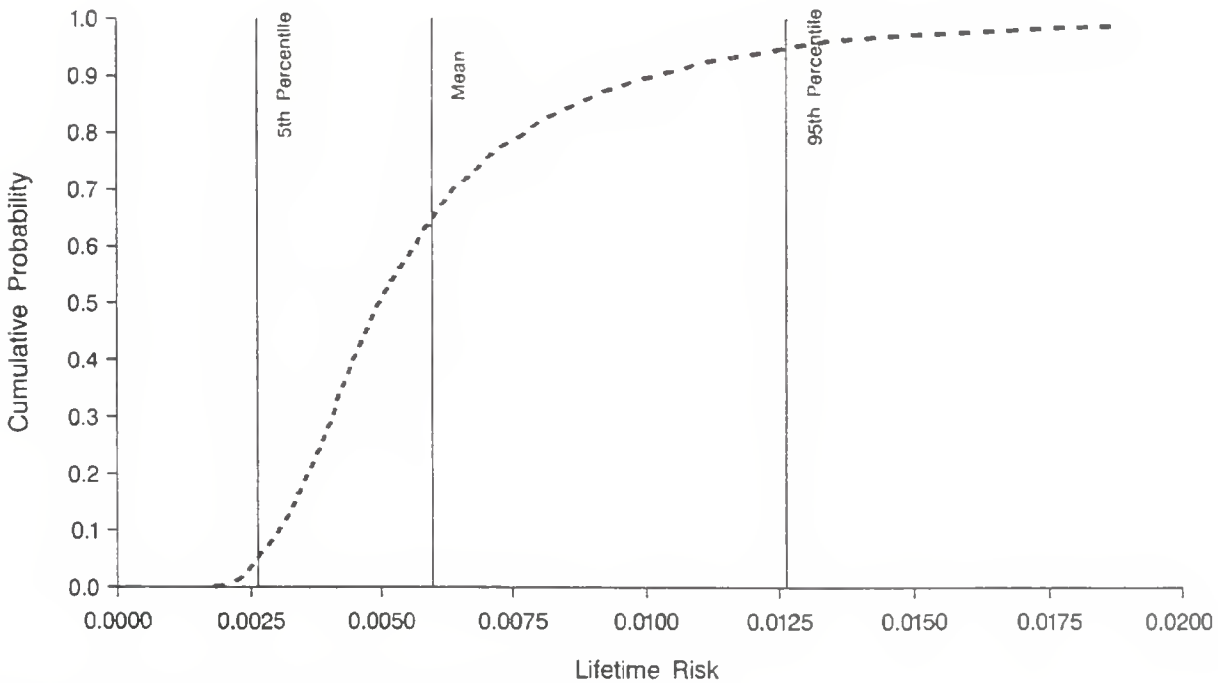


Horizontal axis was truncated at 99th percentile and 11 obs. were not shown.

Figure B.2.35

Distribution of Lifetime Risk for All Age Groups from All Radiological Sources in Zone 3

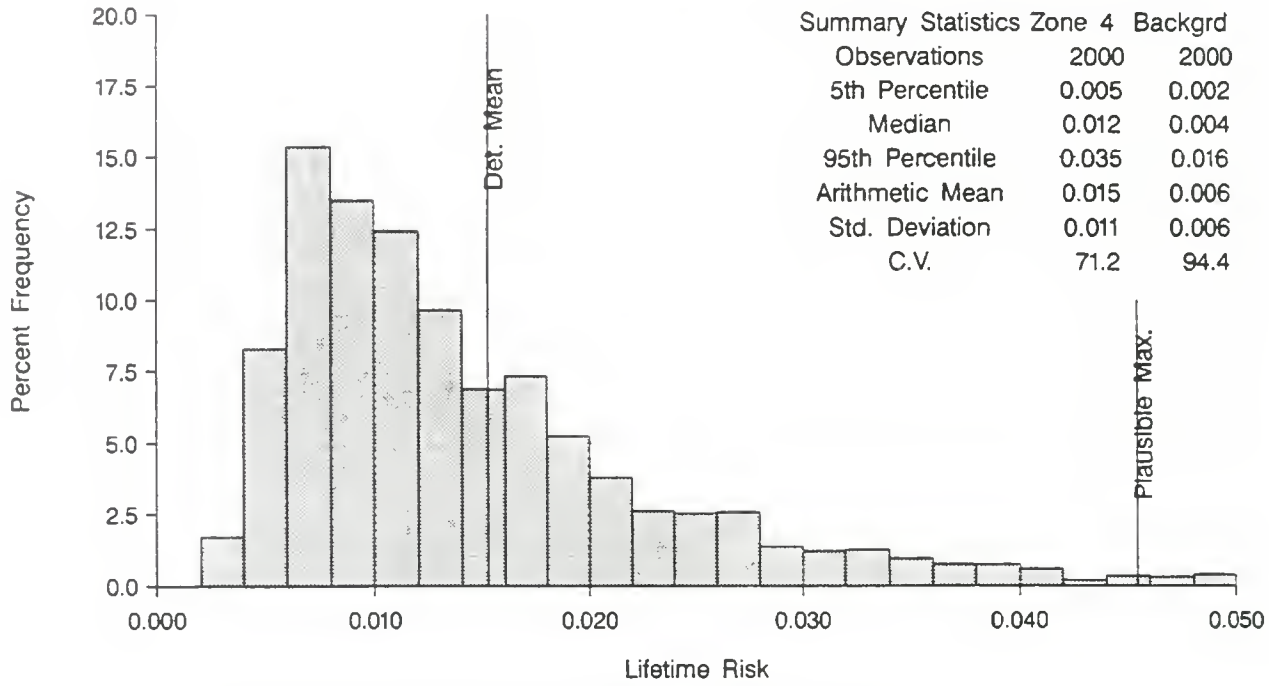


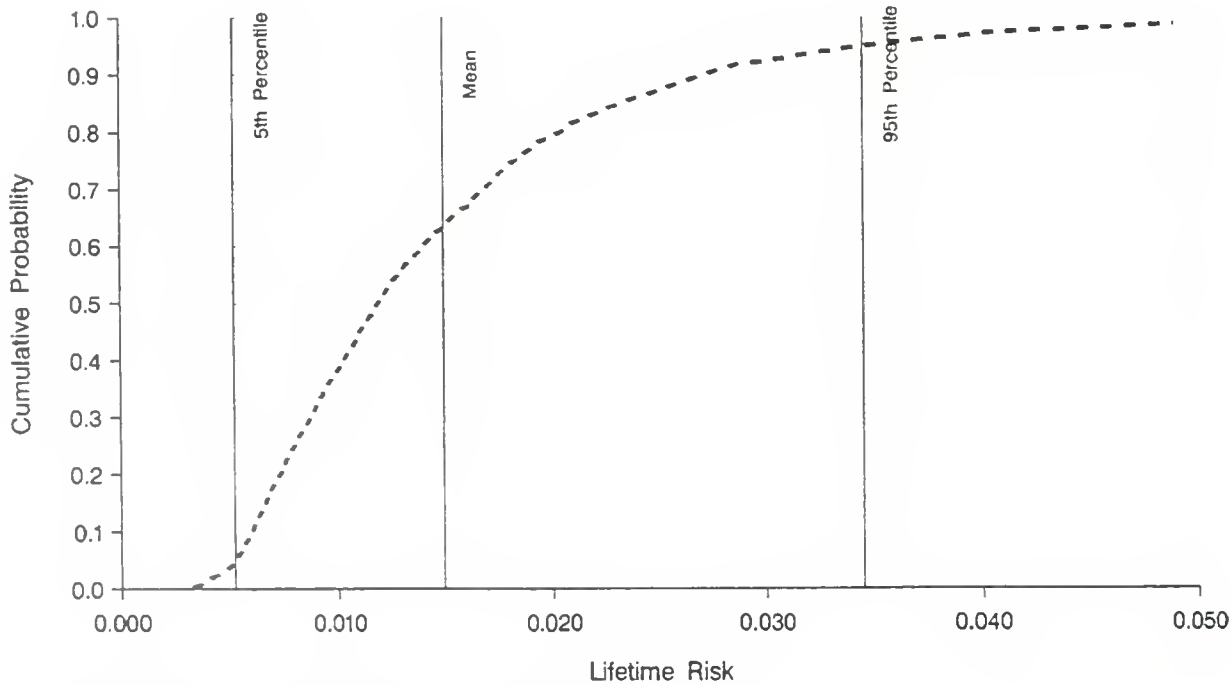


Horizontal axis was truncated at 99th percentile and 16 obs. were not shown.

Figure B.2.36

Distribution of Lifetime Risk for All Age Groups from All Radiological Sources in Zone 4

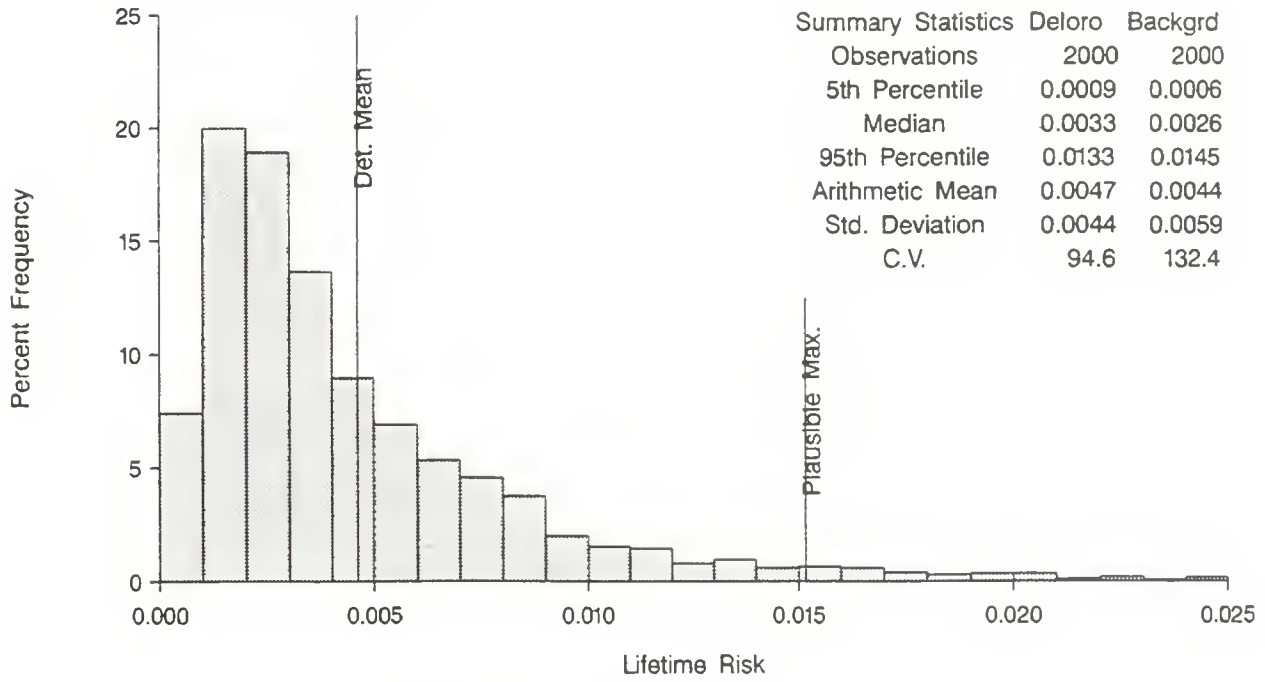


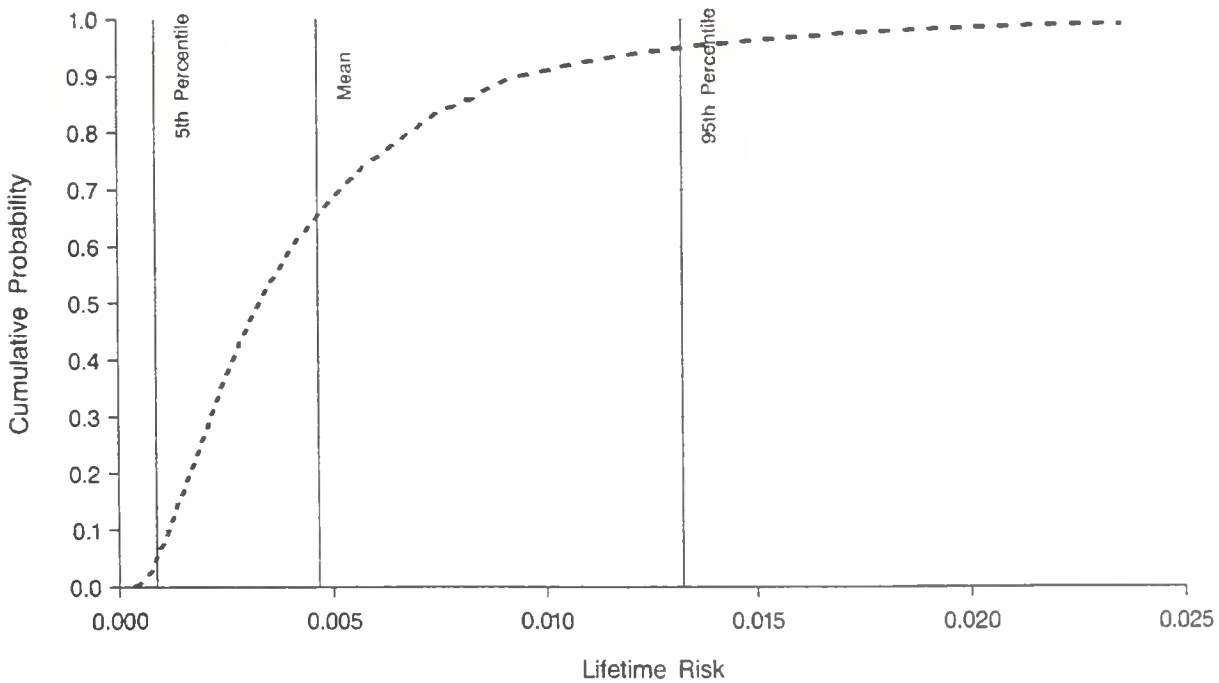


Horizontal axis was truncated at 99th percentile and 19 obs. were not shown.

Figure B.2.37

Distribution of Lifetime Risk for All Age Groups from Radon in Deloro

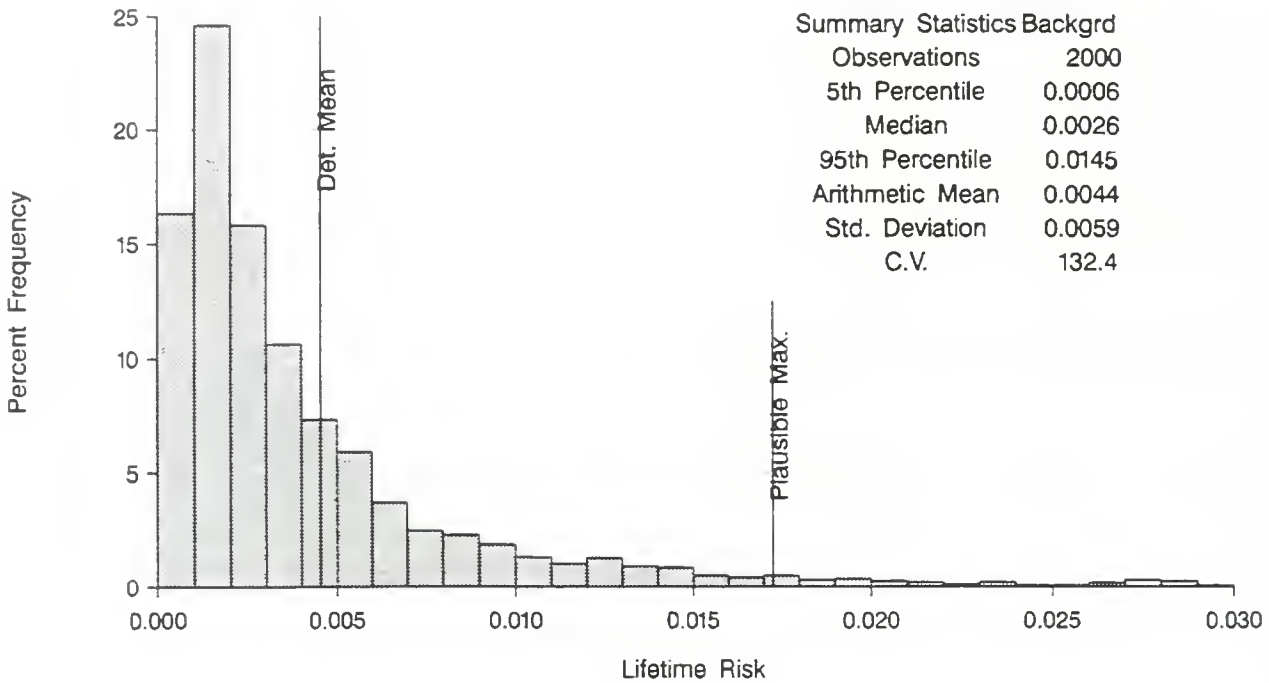


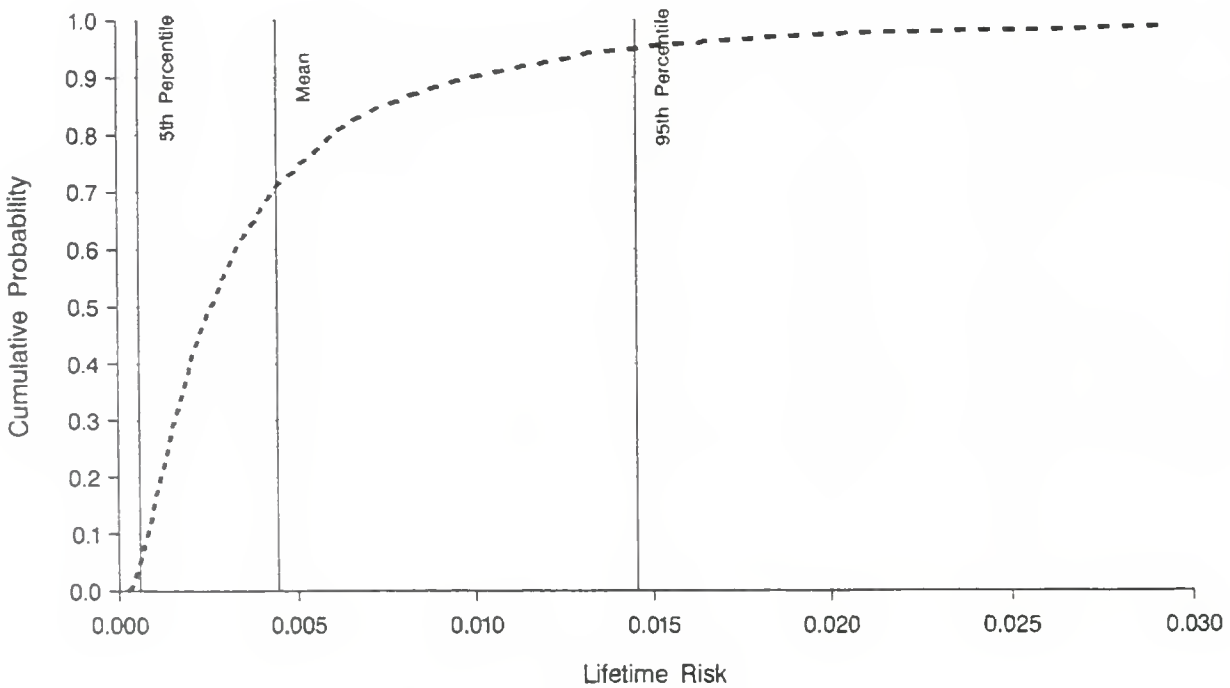


Horizontal axis was truncated at 99th percentile and 11 obs. were not shown.

Figure B.2.38

Distribution of Lifetime Risk for All Age Groups from Radon in Background

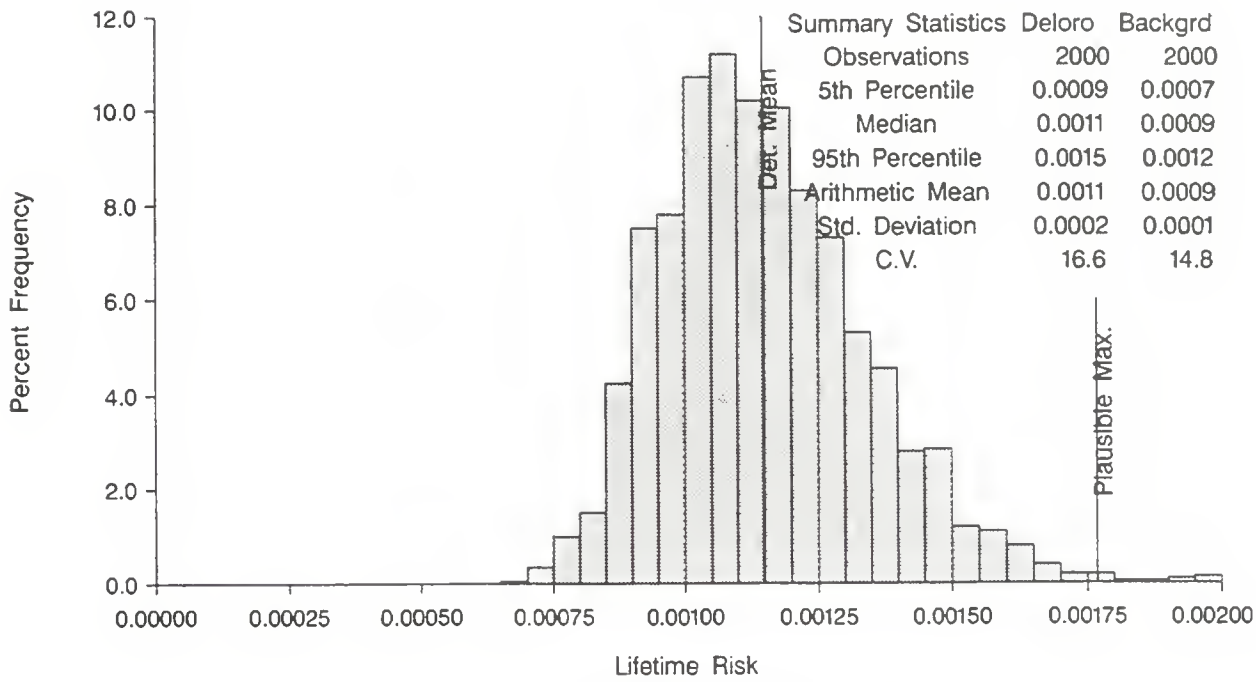


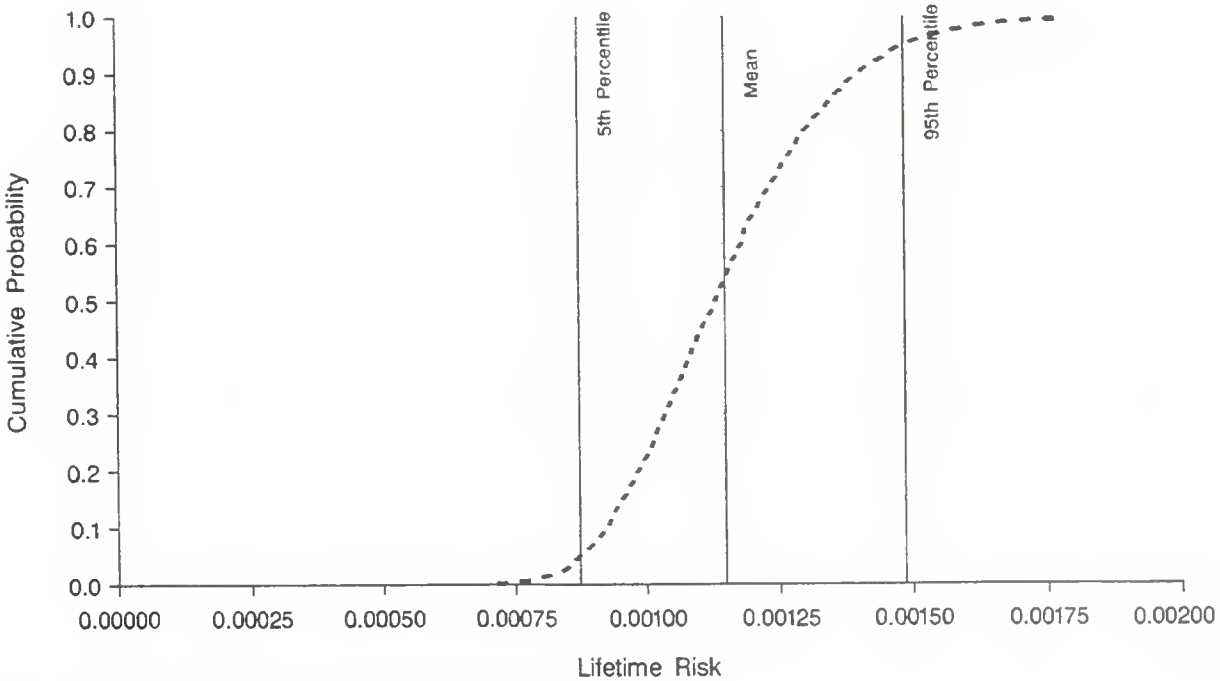


Horizontal axis was truncated at 99th percentile and 18 obs. were not shown.

Figure B.2.39

Distribution of Lifetime Risk for All Age Groups from Gamma in Deloro

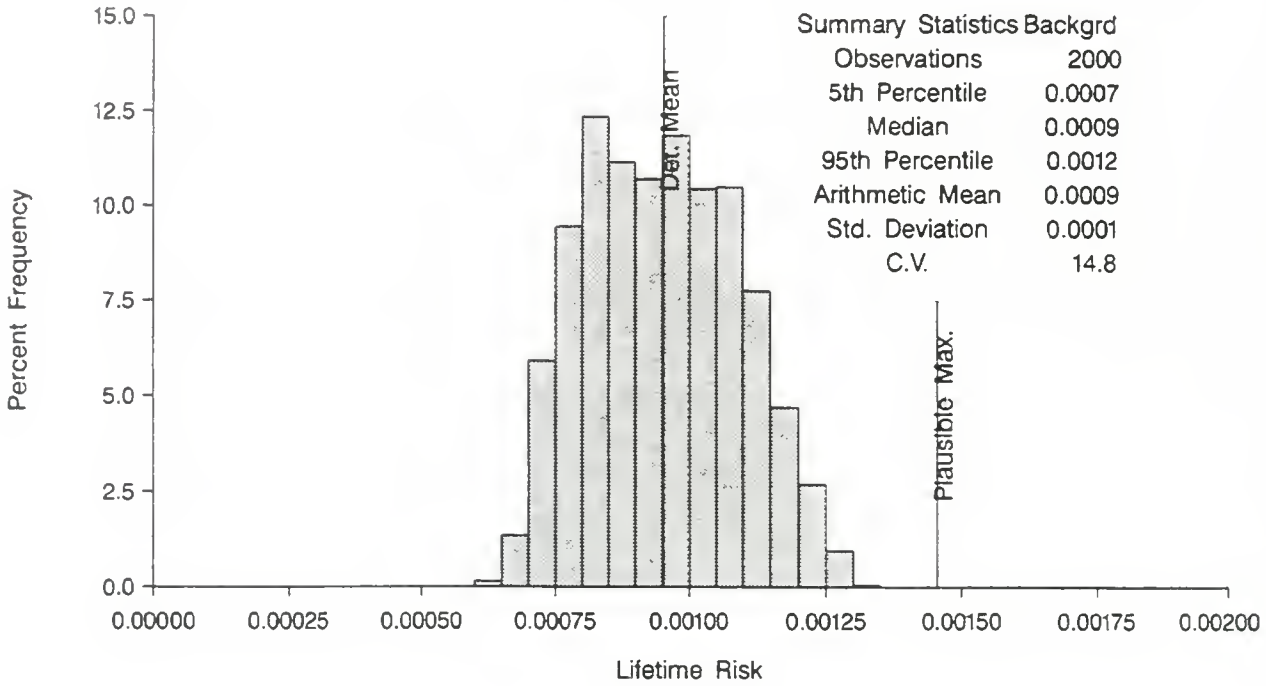




Horizontal axis was truncated at 99th percentile and 1 obs. were not shown.

Figure B.2.40

Distribution of Lifetime Risk for All Age Groups from Gamma in Background



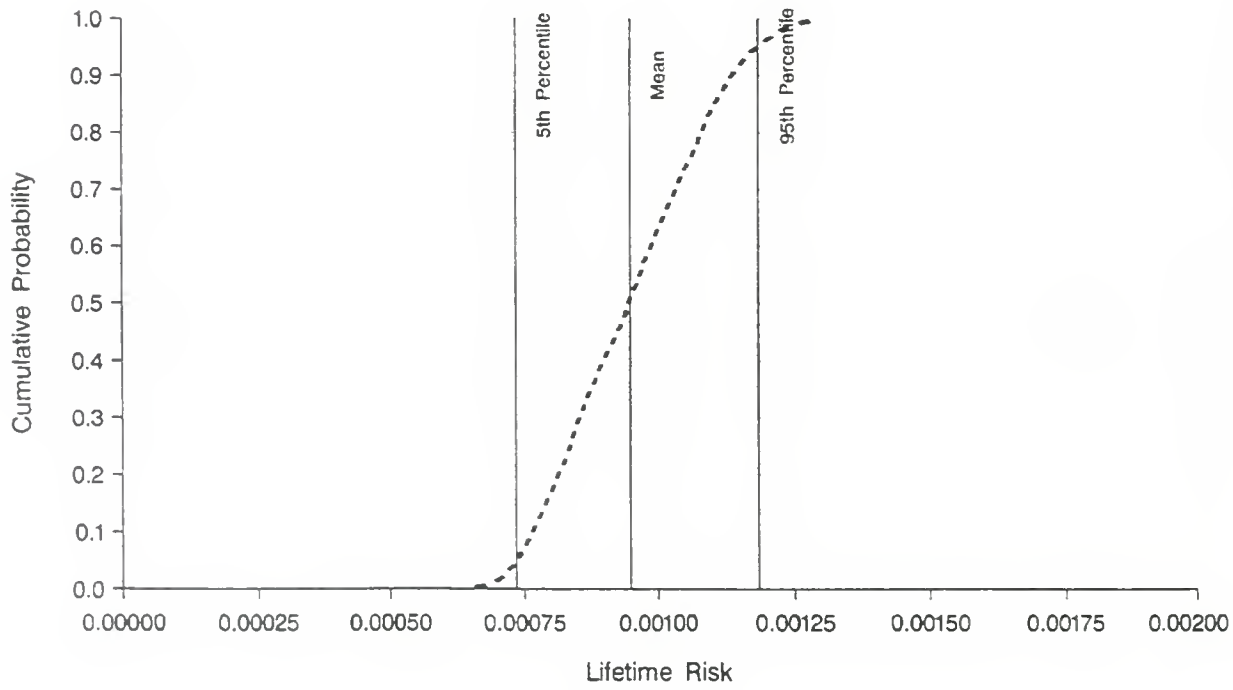
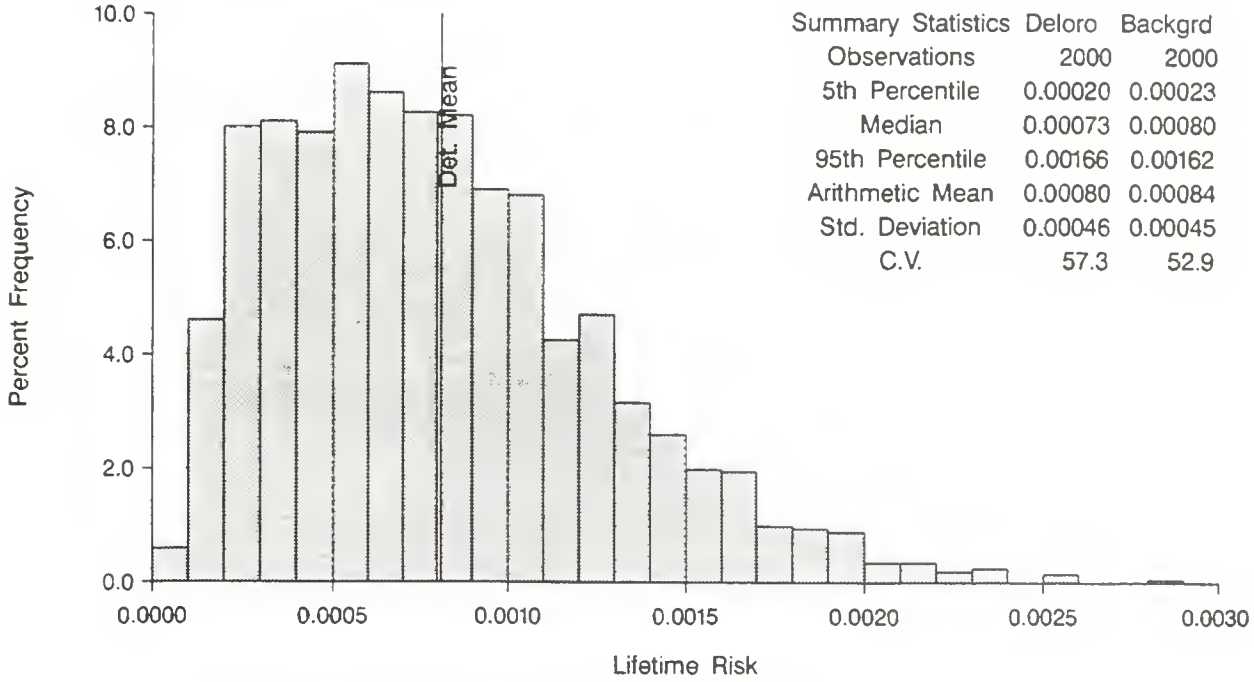
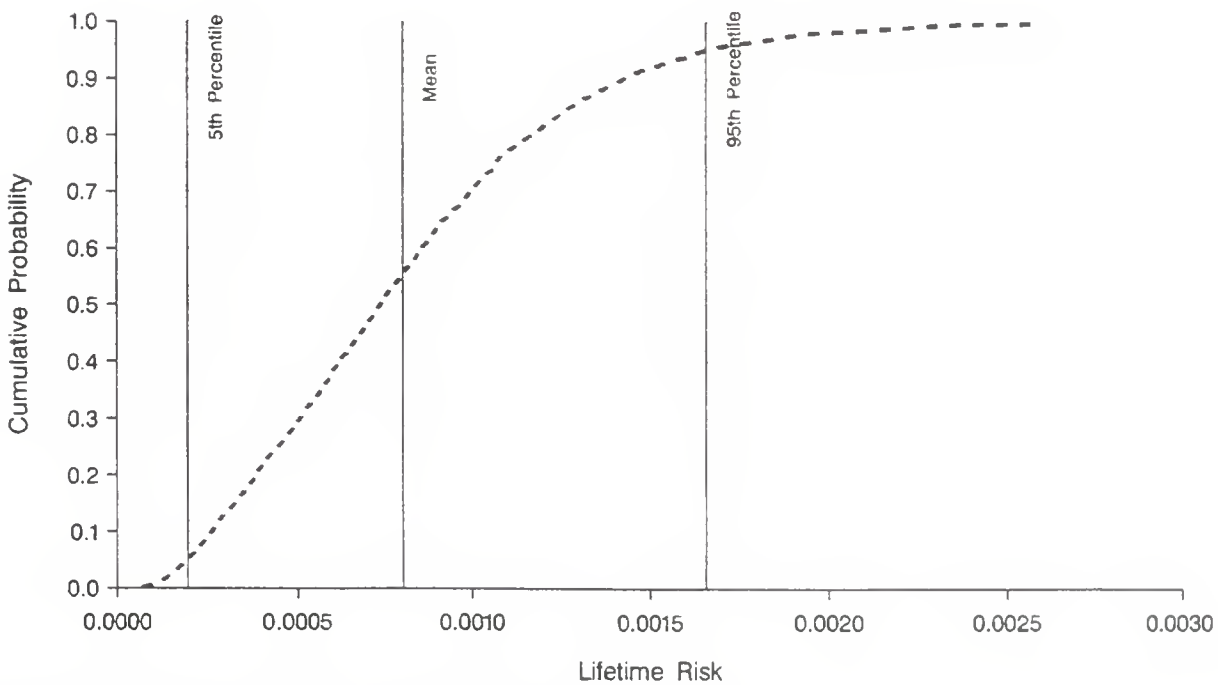


Figure B.2.41

Distribution of Lifetime Risk for All Age Groups from Other Sources in Deloro

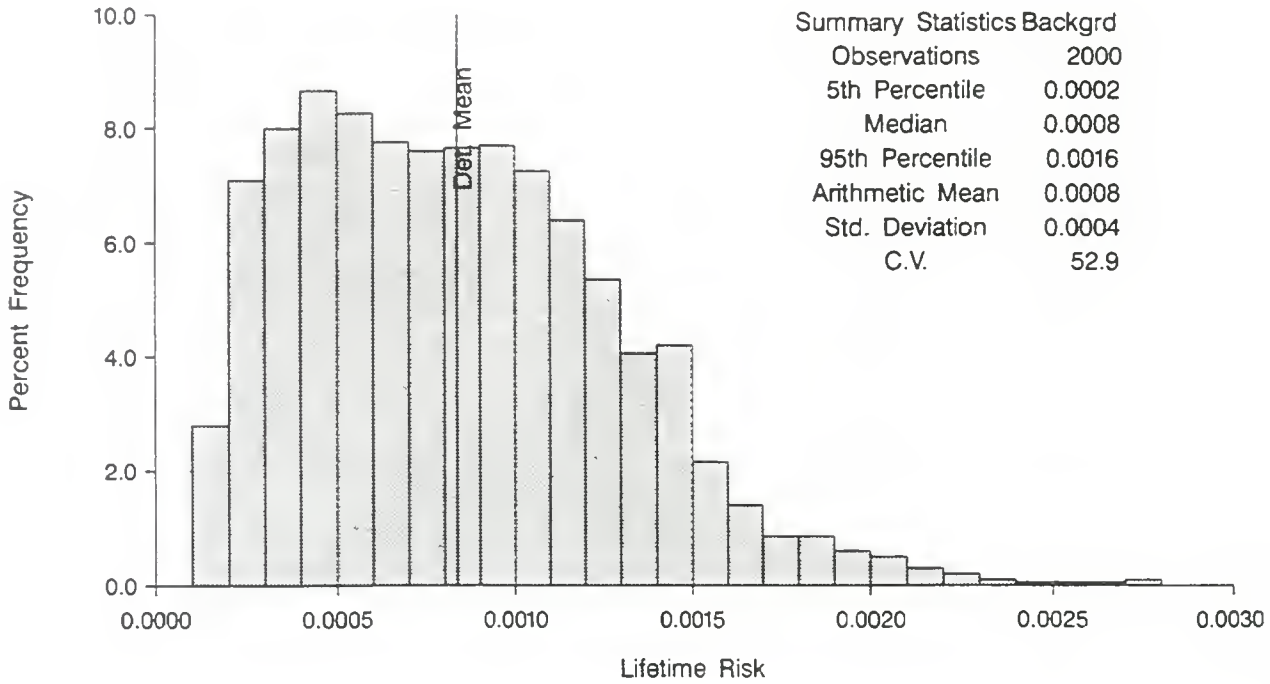


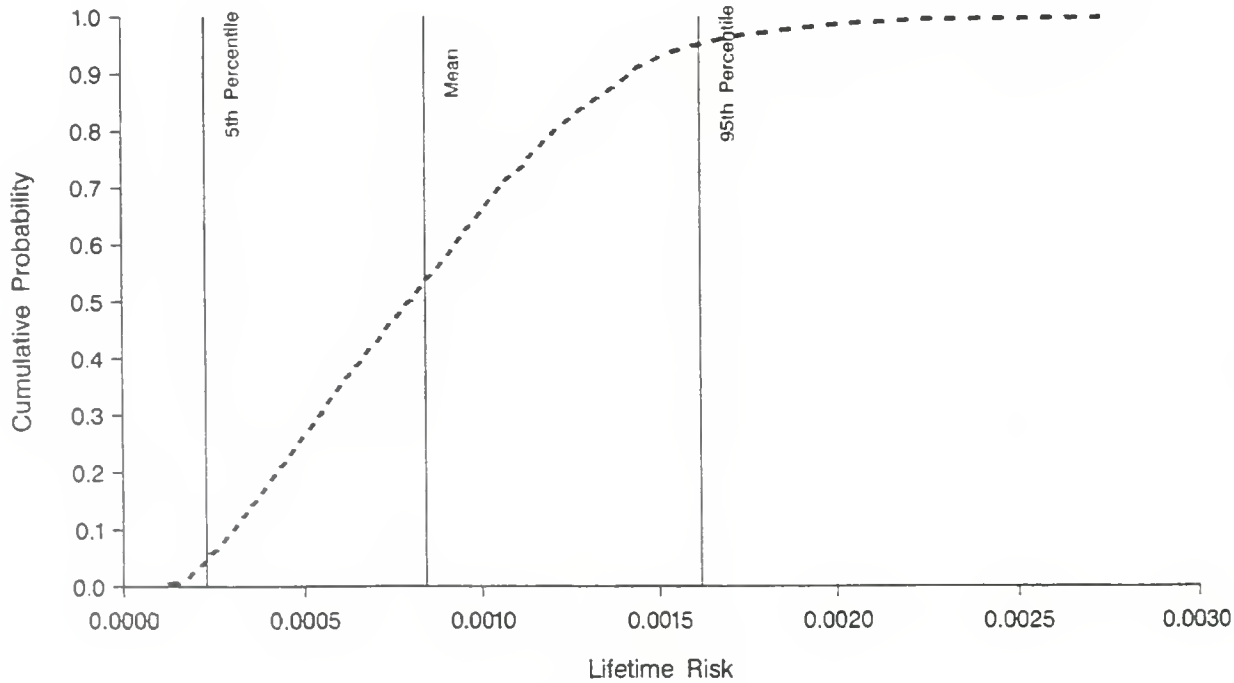


Horizontal axis was truncated at 99th percentile and 2 obs. were not shown.

Figure B.2.42

Distribution of Lifetime Risk for All Age Groups from Other Sources in Background





Horizontal axis was truncated at 99th percentile and 1 obs. were not shown.

Table B.3.1(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 1 year old in Deloro

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00028	19.0	0.00028	0.00036	16
Radon	0.00097	65.4	0.00068	0.0028	94
Water	0.00021	14.0	0.00016	0.00056	86
Other	0.00002	1.6	0.00002	0.00005	66
Total	0.0015	100.0	0.0012	0.0033	63

Table B.3.1(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 1 year old in Deloro

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	94.1	96	Bq/m3	9.617	167
Media	Pb-210 in Water	2.6	59	Bq/L	0.022	0.475
Consumption	Water-01year	1.8	65	L/d	0.188	1.329
Media	U-238 in Water	0.6	40	Bq/L	0.0019	0.010
Consumption	Air-01year	0.1	28	m3/d	5.705	14.385
Media	Ra-226 in Water	0.1	57	Bq/L	0.0056	0.096
Media	Gamma Indoors	0.0	19	uR/h	3.649	6.631
Media	Radon Outdoors	0.0	75	Bq/m3	1.677	15.694
Consumption	Fruit-01year	0.0	78	g/d	58.487	587
Media	Pb-210 in Air	0.0	74	Bq/m3	0.00016	0.0014
Consumption	OtherVeg-01year	0.0	104	g/d	9.739	192
Consumption	RootVeg-01year	0.0	85	g/d	24.067	259
Consumption	SoilDust-01year	0.0	150	g/d	0.0070	0.270
Media	Po-210 in Water	0.0	58	Bq/L	0.00049	0.0095
Media	Gamma Outdoors	0.0	13	uR/h	5.430	8.282
Media	Th-230 in Water	0.0	59	Bq/L	0.00043	0.0095
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Media	U-238 in SoilDust	0.0	43	Bq/g	0.0022	0.0083
Media	Ra-226 in SoilDust	0.0	36	Bq/g	0.0092	0.027
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Media	Po-210 in Air	0.0	51	Bq/m3	9.76E-6	0.00005
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0033
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.380

Table B.3.2(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 5 year old in Deloro

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00025	18.7	0.00025	0.00033	17
Radon	0.0009	66.9	0.00063	0.0026	94
Water	0.00017	12.9	0.00014	0.00042	77
Other	0.00002	1.5	0.00002	0.00005	67
Total	0.0013	100.0	0.0011	0.0031	64

Table B.3.2(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 5 year old in Deloro

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pct Sampled Value
Media	Radon Indoors	94.9	96	Bq/m3	9.617	167
Media	Pb-210 in Water	2.1	59	Bq/L	0.022	0.475
Consumption	Water-05year	0.8	49	L/d	0.333	1.539
Media	U-238 in Water	0.5	40	Bq/L	0.0019	0.010
Consumption	Fruit-05year	0.3	90	g/d	56.995	675
Occupancy	Indoors-Summer-05year	0.2	8	hr/w	99.552	127
Occupancy	Outdoors-Winter-05year	0.1	8	hr/w	9.449	12.128
Consumption	OtherVeg-05year	0.1	115	g/d	15.033	273
Media	Ra-226 in Water	0.1	57	Bq/L	0.0056	0.096
Consumption	Air-05year	0.1	22	m3/d	9.915	20.027
Media	Gamma Indoors	0.1	19	uR/h	3.649	6.631
Consumption	SoilDust-05year	0.1	152	g/d	0.0072	0.256
Occupancy	Indoors-Winter-05year	0.1	8	hr/w	105	133
Media	Radon Outdoors	0.0	75	Bq/m3	1.677	15.694
Media	Pb-210 in Air	0.0	74	Bq/m3	0.00016	0.0014
Consumption	RootVeg-05year	0.0	86	g/d	33.149	426
Media	Gamma Outdoors	0.0	13	uR/h	5.430	8.282
Media	Po-210 in Water	0.0	58	Bq/L	0.00049	0.0095
Occupancy	Outdoors-Summer-05year	0.0	17	hr/w	14.716	25.582
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141
Media	Th-230 in Water	0.0	59	Bq/L	0.00043	0.0095
Media	Po-210 in Air	0.0	51	Bq/m3	9.76E-6	0.00005
Media	Ra-226 in SoilDust	0.0	36	Bq/g	0.0092	0.027
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Media	U-238 in SoilDust	0.0	43	Bq/g	0.0022	0.0081
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0031
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698

Table B.3.3(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 10 year old in Deloro

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00023	17.8	0.00023	0.0003	17
Radon	0.0009	69.5	0.00063	0.0025	94
Water	0.00015	11.6	0.00012	0.00036	76
Other	0.00001	1.1	0.00001	0.00003	69
Total	0.0013	100.0	0.0010	0.0030	66

Table B.3.3(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 10 year old in Deloro

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	95.3	96	Bq/m3	9.617	167
Media	Pb-210 in Water	1.7	59	Bq/L	0.022	0.475
Consumption	Water-10year	1.3	49	L/d	0.327	1.518
Media	U-238 in Water	0.6	40	Bq/L	0.0019	0.010
Occupancy	Indoors-Summer-10year	0.2	8	hr/w	99.571	127
Media	Ra-226 in Water	0.1	57	Bq/L	0.0056	0.096
Occupancy	Outdoors-Summer-10year	0.1	18	hr/w	14.554	25.803
Consumption	Air-10year	0.1	23	m3/d	9.854	20.263
Media	Radon Outdoors	0.0	75	Bq/m3	1.677	15.694
Occupancy	Outdoors-Winter-10year	0.0	8	hr/w	9.476	12.142
Media	Gamma Indoors	0.0	19	uR/h	3.649	6.631
Media	Pb-210 in Air	0.0	74	Bq/m3	0.00016	0.0014
Occupancy	Indoors-Winter-10year	0.0	8	hr/w	105	133
Media	Po-210 in Water	0.0	58	Bq/L	0.00049	0.0095
Consumption	SoilDust-10year	0.0	155	g/d	0.0067	0.256
Media	Gamma Outdoors	0.0	13	uR/h	5.430	8.282
Consumption	OtherVeg-10year	0.0	120	g/d	16.082	293
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Media	Th-230 in Water	0.0	59	Bq/L	0.00043	0.0095
Consumption	RootVeg-10year	0.0	90	g/d	33.368	424
Media	Po-210 in Air	0.0	51	Bq/m3	9.76E-6	0.00005
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Media	Ra-226 in SoilDust	0.0	36	Bq/g	0.0092	0.027
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Consumption	Fruit-10year	0.0	86	g/d	55.969	679
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0033
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Media	U-238 in SoilDust	0.0	43	Bq/g	0.0022	0.0083

Table B.3.4(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 15 year old in Deloro

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.0002	16.3	0.0002	0.00026	17
Radon	0.00083	66.5	0.00059	0.0024	94
Water	0.0002	16.2	0.00016	0.00054	85
Other	0.00001	1.0	0.00001	0.00003	67
Total	0.0012	100.0	0.0010	0.0028	65

Table B.3.4(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 15 year old in Deloro

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pct Sampled Value
Media	Radon Indoors	91.1	96	Bq/m3	9.617	167
Media	Pb-210 in Water	2.6	59	Bq/L	0.022	0.475
Consumption	Water-15year	2.6	61	L/d	0.352	2.238
Occupancy	Indoors-Summer-15year	1.4	10	hr/w	87.366	119
Media	U-238 in Water	0.6	40	Bq/L	0.0019	0.010
Media	Ra-226 in Water	0.2	57	Bq/L	0.0056	0.096
Consumption	OtherVeg-15year	0.2	111	g/d	18.583	372
Consumption	Fruit-15year	0.1	93	g/d	49.023	664
Media	Radon Outdoors	0.0	75	Bq/m3	1.677	15.694
Consumption	RootVeg-15year	0.0	79	g/d	60.447	580
Media	Po-210 in Water	0.0	58	Bq/L	0.00049	0.0095
Occupancy	Indoors-Winter-15year	0.0	12	hr/w	92.102	133
Consumption	Air-15year	0.0	26	m3/d	10.124	23.006
Media	Gamma Indoors	0.0	19	uR/h	3.649	6.631
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Media	Th-230 in Water	0.0	59	Bq/L	0.00043	0.0095
Consumption	SoilDust-15year	0.0	40	g/d	0.024	0.096
Media	Gamma Outdoors	0.0	13	uR/h	5.430	8.282
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Media	Ra-226 in SoilDust	0.0	36	Bq/g	0.0092	0.027
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Media	Pb-210 in Air	0.0	74	Bq/m3	0.00016	0.0014
Media	U-238 in SoilDust	0.0	43	Bq/g	0.0022	0.0083
Occupancy	Outdoors-Winter-15year	0.0	11	hr/w	8.388	12.056
Occupancy	Outdoors-Summer-15year	0.0	21	hr/w	12.816	25.731
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0031
Media	Po-210 in Air	0.0	51	Bq/m3	9.76E-6	0.00005
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141

Table B.3.5(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for Adult in Deloro

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.0002	16.8	0.00019	0.00026	18
Radon	0.00085	73.1	0.00059	0.0024	96
Water	0.00011	9.2	0.00008	0.00028	83
Other	9.58E-6	0.8	7.82E-6	0.00002	69
Total	0.0012	100.0	0.00091	0.0027	71

Table B.3.5(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for Adult in Deloro

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	95.4	96	Bq/m3	9.617	167
Media	Pb-210 in Water	1.1	59	Bq/L	0.022	0.475
Occupancy	Indoors-Summer-Adult	0.8	11	hr/w	88.057	127
Media	U-238 in Water	0.6	40	Bq/L	0.0019	0.010
Consumption	Water-Adult	0.6	54	L/d	0.585	2.979
Occupancy	Indoors-Winter-Adult	0.4	12	hr/w	92.276	132
Occupancy	Outdoors-Winter-Adult	0.1	11	hr/w	8.350	12.036
Occupancy	Outdoors-Summer-Adult	0.1	12	hr/w	12.493	18.048
Media	Ra-226 in Water	0.1	57	Bq/L	0.0056	0.096
Media	Radon Outdoors	0.0	75	Bq/m3	1.677	15.694
Consumption	Fruit-Adult	0.0	81	g/d	57.514	643
Consumption	OtherVeg-Adult	0.0	96	g/d	27.887	366
Media	Gamma Indoors	0.0	19	uR/h	3.649	6.631
Consumption	SoilDust-Adult	0.0	38	g/d	0.024	0.096
Consumption	RootVeg-Adult	0.0	81	g/d	47.751	452
Consumption	Air-Adult	0.0	25	m3/d	10.283	23.320
Media	Po-210 in Water	0.0	58	Bq/L	0.00049	0.0095
Media	Pb-210 in Air	0.0	74	Bq/m3	0.00016	0.0014
Media	Gamma Outdoors	0.0	13	uR/h	5.430	8.282
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0033
Media	Po-210 in Air	0.0	51	Bq/m3	9.76E-6	0.00005
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696
Media	U-238 in SoilDust	0.0	43	Bq/g	0.0022	0.0083
Media	Ra-226 in SoilDust	0.0	36	Bq/g	0.0092	0.027
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141
Media	Th-230 in Water	0.0	59	Bq/L	0.00043	0.0095
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698

Table B.3.6(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 1 year old in Background

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00023	16.6	0.00023	0.00029	14
Radon	0.00093	65.6	0.00054	0.0030	132
Water	0.00022	15.4	0.00016	0.00059	90
Other	0.00003	2.4	0.00003	0.00006	50
Total	0.0014	100.0	0.0010	0.0037	87

Table B.3.6(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 1 year old in Background

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pc Sample Valu
Media	Radon Indoors	97.3	138	Bq/m3	4.785	18
Consumption	Water-01year	1.3	65	L/d	0.188	1.32
Media	Pb-210 in Water	0.4	58	Bq/L	0.025	0.47
Consumption	Fruit-01year	0.3	78	g/d	58.487	58
Media	Po-210 in Water	0.2	58	Bq/L	0.00049	0.009
Media	Gamma Indoors	0.0	16	uR/h	3.120	5.18
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.01
Consumption	Air-01year	0.0	28	m3/d	5.705	14.38
Consumption	SoilDust-01year	0.0	150	g/d	0.0070	0.27
Media	Ra-226 in Water	0.0	59	Bq/L	0.0053	0.09
Media	Gamma Outdoors	0.0	26	uR/h	3.244	7.77
Media	Radon Outdoors	0.0	26	Bq/m3	6.531	15.45
Consumption	RootVeg-01year	0.0	85	g/d	24.067	25
Consumption	OtherVeg-01year	0.0	104	g/d	9.739	19
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.69
Media	Pb-210 in Air	0.0	35	Bq/m3	0.0004	0.001
Media	U-238 in SoilDust	0.0	136	Bq/g	0	0.93
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14
Media	Th-230 in Water	0.0	57	Bq/L	0.00059	0.009
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69
Media	Ra-226 in SoilDust	0.0	29	Bq/g	0.013	0.03
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.01
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008
Media	Po-210 in Air	0.0	34	Bq/m3	0.00004	0.0001
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.38

Table B.3.7(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 5 year old in Background

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00021	16.4	0.00021	0.00026	15
Radon	0.00086	67.6	0.0005	0.0028	133
Water	0.00018	13.8	0.00014	0.00043	76
Other	0.00003	2.2	0.00003	0.00005	47
Total	0.0013	100.0	0.00094	0.0032	91

Table B.3.7(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 5 year old in Background

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	96.8	138	Bq/m3	4.785	180
Consumption	Water-05year	0.7	49	L/d	0.333	1.539
Consumption	OtherVeg-05year	0.6	115	g/d	15.033	273
Occupancy	Indoors-Summer-05year	0.5	8	hr/w	99.552	127
Media	Pb-210 in Water	0.3	58	Bq/L	0.025	0.474
Occupancy	Indoors-Winter-05year	0.2	8	hr/w	105	133
Consumption	SoilDust-05year	0.2	152	g/d	0.0072	0.256
Media	Po-210 in Water	0.2	58	Bq/L	0.00049	0.0095
Media	Gamma Indoors	0.1	16	uR/h	3.120	5.182
Occupancy	Outdoors-Winter-05year	0.0	8	hr/w	9.449	12.128
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.010
Media	Ra-226 in Water	0.0	59	Bq/L	0.0053	0.095
Media	Radon Outdoors	0.0	26	Bq/m3	6.531	15.455
Consumption	Air-05year	0.0	22	m3/d	9.915	20.027
Media	Gamma Outdoors	0.0	26	uR/h	3.244	7.770
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Media	Th-230 in Water	0.0	57	Bq/L	0.00059	0.0095
Consumption	Fruit-05year	0.0	90	g/d	56.995	675
Media	Pb-210 in Air	0.0	35	Bq/m3	0.0004	0.0012
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Occupancy	Outdoors-Summer-05year	0.0	17	hr/w	14.716	25.582
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Media	U-238 in SoilDust	0.0	136	Bq/g	0	0.935
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0033
Media	Po-210 in Air	0.0	34	Bq/m3	0.00004	0.00012
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696
Consumption	RootVeg-05year	0.0	86	g/d	33.149	426
Media	Ra-226 in SoilDust	0.0	29	Bq/g	0.013	0.036
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141

Table B.3.8(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 10 year old in Background

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00019	15.6	0.00019	0.00024	15
Radon	0.00086	70.4	0.00049	0.0028	133
Water	0.00015	12.4	0.00013	0.00036	74
Other	0.00002	1.6	0.00002	0.00004	49
Total	0.0012	100.0	0.00087	0.0032	94

Table B.3.8(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 10 year old in Background

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pc Sample Valu
Media	Radon Indoors	96.9	138	Bq/m3	4.785	18
Consumption	Water-10year	1.2	49	L/d	0.327	1.51
Consumption	OtherVeg-10year	0.3	120	g/d	16.082	29
Consumption	Air-10year	0.2	23	m3/d	9.854	20.26
Occupancy	Indoors-Summer-10year	0.2	8	hr/w	99.571	12
Media	Po-210 in Water	0.2	58	Bq/L	0.00049	0.009
Media	Pb-210 in Water	0.1	58	Bq/L	0.025	0.47
Occupancy	Outdoors-Summer-10year	0.1	18	hr/w	14.554	25.80
Consumption	RootVeg-10year	0.1	90	g/d	33.368	42
Occupancy	Indoors-Winter-10year	0.1	8	hr/w	105	13
Media	Gamma Indoors	0.1	16	uR/h	3.120	5.18
Occupancy	Outdoors-Winter-10year	0.0	8	hr/w	9.476	12.14
Consumption	Fruit-10year	0.0	86	g/d	55.969	67
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.01
Media	Ra-226 in Water	0.0	59	Bq/L	0.0053	0.09
Media	Radon Outdoors	0.0	26	Bq/m3	6.531	15.45
Media	Pb-210 in Air	0.0	35	Bq/m3	0.0004	0.001
Media	Gamma Outdoors	0.0	26	uR/h	3.244	7.77
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14
Consumption	SoilDust-10year	0.0	155	g/d	0.0067	0.25
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.01
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.69
Media	U-238 in SoilDust	0.0	136	Bq/g	0	0.93
Media	Th-230 in Water	0.0	57	Bq/L	0.00059	0.009
Media	Ra-226 in SoilDust	0.0	29	Bq/g	0.013	0.03
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Media	Po-210 in Air	0.0	34	Bq/m3	0.00004	0.0001

Table B.3.9(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 15 year old in Background

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00017	14.2	0.00017	0.00021	16
Radon	0.00079	66.8	0.00046	0.0026	133
Water	0.00021	17.3	0.00016	0.00054	84
Other	0.00002	1.7	0.00002	0.00004	57
Total	0.0012	100.0	0.00089	0.0030	89

Table B.3.9(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 15 year old in Background

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	96.7	138	Bq/m3	4.785	180
Consumption	Water-15year	1.0	61	L/d	0.352	2.238
Occupancy	Indoors-Summer-15year	0.6	10	hr/w	87.366	119
Media	Pb-210 in Water	0.4	58	Bq/L	0.025	0.474
Media	Po-210 in Water	0.2	58	Bq/L	0.00049	0.0095
Consumption	RootVeg-15year	0.1	79	g/d	60.447	580
Media	Gamma Indoors	0.1	16	uR/h	3.120	5.182
Occupancy	Outdoors-Summer-15year	0.0	21	hr/w	12.816	25.731
Consumption	OtherVeg-15year	0.0	111	g/d	18.583	372
Occupancy	Indoors-Winter-15year	0.0	12	hr/w	92.102	133
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.010
Consumption	Fruit-15year	0.0	93	g/d	49.023	664
Media	Radon Outdoors	0.0	26	Bq/m3	6.531	15.455
Consumption	SoilDust-15year	0.0	40	g/d	0.024	0.096
Occupancy	Outdoors-Winter-15year	0.0	11	hr/w	8.388	12.056
Media	Gamma Outdoors	0.0	26	uR/h	3.244	7.770
Consumption	Air-15year	0.0	26	m3/d	10.124	23.006
Media	Ra-226 in Water	0.0	59	Bq/L	0.0053	0.095
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Media	U-238 in SoilDust	0.0	136	Bq/g	0	0.935
Media	Th-230 in Water	0.0	57	Bq/L	0.00059	0.0095
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0033
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Media	Pb-210 in Air	0.0	35	Bq/m3	0.0004	0.0012
Media	Po-210 in Air	0.0	34	Bq/m3	0.00004	0.00012
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141
Media	Ra-226 in SoilDust	0.0	29	Bq/g	0.013	0.036

Table B.3.10(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for Adult in Background

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00016	14.8	0.00016	0.00021	16
Radon	0.00081	74.1	0.00047	0.0026	133
Water	0.00011	9.8	0.00009	0.00026	77
Other	0.00001	1.3	0.00001	0.00002	44
Total	0.0011	100.0	0.00075	0.0029	98

Table B.3.10(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for Adult in Background

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pc Sample Value
Media	Radon Indoors	97.8	138	Bq/m3	4.785	18
Occupancy	Indoors-Summer-Adult	0.5	11	hr/w	88.057	12
Consumption	Water-Adult	0.2	54	L/d	0.585	2.97
Consumption	Fruit-Adult	0.2	81	g/d	57.514	64
Media	Po-210 in Water	0.2	58	Bq/L	0.00049	0.009
Consumption	Air-Adult	0.1	25	m3/d	10.283	23.32
Occupancy	Outdoors-Winter-Adult	0.1	11	hr/w	8.350	12.03
Media	Gamma Indoors	0.1	16	uR/h	3.120	5.18
Consumption	SoilDust-Adult	0.1	38	g/d	0.024	0.09
Consumption	RootVeg-Adult	0.0	81	g/d	47.751	45
Media	Pb-210 in Water	0.0	58	Bq/L	0.025	0.47
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.01
Occupancy	Indoors-Winter-Adult	0.0	12	hr/w	92.276	13
Media	Ra-226 in Water	0.0	59	Bq/L	0.0053	0.09
Media	Radon Outdoors	0.0	26	Bq/m3	6.531	15.45
Media	Gamma Outdoors	0.0	26	uR/h	3.244	7.77
Media	Pb-210 in Air	0.0	35	Bq/m3	0.0004	0.001
Media	Th-230 in Water	0.0	57	Bq/L	0.00059	0.009
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.69
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Media	Ra-226 in SoilDust	0.0	29	Bq/g	0.013	0.03
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Consumption	OtherVeg-Adult	0.0	96	g/d	27.887	36
Media	U-238 in SoilDust	0.0	136	Bq/g	0	0.93
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008
Occupancy	Outdoors-Summer-Adult	0.0	12	hr/w	12.493	18.04
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.01
Media	Po-210 in Air	0.0	34	Bq/m3	0.00004	0.0001
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01

Table B.3.11(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 1 year old in Zone 1

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00027	13.6	0.00026	0.00035	17
Radon	0.0015	74.3	0.0010	0.0041	103
Water	0.00022	11.1	0.00017	0.00059	90
Other	0.00002	1.1	0.00002	0.00005	74
Total	0.0020	100.0	0.0015	0.0045	77

Table B.3.11(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 1 year old in Zone 1

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	98.6	105	Bq/m3	15.376	244
Consumption	Water-01year	0.6	65	L/d	0.188	1.329
Media	Pb-210 in Water	0.1	58	Bq/L	0.022	0.475
Media	Ra-226 in Water	0.1	59	Bq/L	0.0051	0.095
Media	Gamma Indoors	0.1	19	uR/h	3.391	6.405
Consumption	SoilDust-01year	0.1	150	g/d	0.0070	0.270
Consumption	OtherVeg-01year	0.0	104	g/d	9.739	192
Media	Po-210 in Water	0.0	58	Bq/L	0.00054	0.0095
Consumption	Air-01year	0.0	28	m3/d	5.705	14.385
Consumption	Fruit-01year	0.0	78	g/d	58.487	587
Media	Radon Outdoors	0.0	58	Bq/m3	0.543	9.530
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.010
Consumption	RootVeg-01year	0.0	85	g/d	24.067	259
Media	Pb-210 in Air	0.0	79	Bq/m3	0.00011	0.0012
Media	Gamma Outdoors	0.0	9	uR/h	5.216	7.034
Media	Th-230 in Water	0.0	57	Bq/L	0.00055	0.0095
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0033
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Media	U-238 in SoilDust	0.0	19	Bq/g	0.0028	0.0052
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141
Media	Po-210 in Air	0.0	59	Bq/m3	2.83E-6	0.00006
Media	Ra-226 in SoilDust	0.0	54	Bq/g	0.0063	0.032
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.380

Table B.3.12(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 5 year old in Zone 1

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00024	13.3	0.00023	0.00031	17
Radon	0.0013	75.7	0.00094	0.0037	103
Water	0.00018	10.0	0.00014	0.00045	79
Other	0.00002	0.9	0.00001	0.00004	71
Total	0.0018	100.0	0.0014	0.0041	78

Table B.3.12(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 5 year old in Zone 1

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pc Sample Valu
Media	Radon Indoors	97.8	105	Bq/m3	15.376	24
Consumption	Water-05year	0.6	49	L/d	0.333	1.53
Occupancy	Indoors-Winter-05year	0.4	8	hr/w	105	13
Media	Gamma Indoors	0.1	19	uR/h	3.391	6.40
Media	Ra-226 in Water	0.1	59	Bq/L	0.0051	0.09
Occupancy	Outdoors-Winter-05year	0.1	8	hr/w	9.449	12.12
Consumption	RootVeg-05year	0.1	86	g/d	33.149	42
Occupancy	Indoors-Summer-05year	0.1	8	hr/w	99.552	12
Media	Pb-210 in Water	0.1	58	Bq/L	0.022	0.47
Media	Po-210 in Water	0.0	58	Bq/L	0.00054	0.009
Consumption	Fruit-05year	0.0	90	g/d	56.995	67
Consumption	Air-05year	0.0	22	m3/d	9.915	20.02
Consumption	SoilDust-05year	0.0	152	g/d	0.0072	0.25
Media	Radon Outdoors	0.0	58	Bq/m3	0.543	9.53
Occupancy	Outdoors-Summer-05year	0.0	17	hr/w	14.716	25.58
Media	Pb-210 in Air	0.0	79	Bq/m3	0.00011	0.001
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.01
Media	Ra-226 in SoilDust	0.0	54	Bq/g	0.0063	0.03
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.69
Consumption	OtherVeg-05year	0.0	115	g/d	15.033	27
Media	Th-230 in Water	0.0	57	Bq/L	0.00055	0.009
Media	Gamma Outdoors	0.0	9	uR/h	5.216	7.03
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.01
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008
Media	Po-210 in Air	0.0	59	Bq/m3	2.83E-6	0.0000
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Media	U-238 in SoilDust	0.0	19	Bq/g	0.0028	0.005

Table B.3.13(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 10 year old in Zone 1

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00022	12.6	0.00021	0.00028	17
Radon	0.0013	77.9	0.00094	0.0036	104
Water	0.00015	8.8	0.00013	0.00037	76
Other	0.00001	0.7	9.45E-6	0.00003	70
Total	0.0017	100.0	0.0013	0.0041	81

Table B.3.13(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 10 year old in Zone 1

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	98.3	105	Bq/m3	15.376	244
Occupancy	Indoors-Summer-10year	0.4	8	hr/w	99.571	127
Consumption	Water-10year	0.3	49	L/d	0.327	1.518
Consumption	RootVeg-10year	0.3	90	g/d	33.368	424
Media	Ra-226 in Water	0.1	59	Bq/L	0.0051	0.095
Media	Gamma Indoors	0.1	19	uR/h	3.391	6.405
Media	Po-210 in Water	0.1	58	Bq/L	0.00054	0.0095
Media	Pb-210 in Water	0.1	58	Bq/L	0.022	0.475
Occupancy	Outdoors-Summer-10year	0.0	18	hr/w	14.554	25.803
Occupancy	Outdoors-Winter-10year	0.0	8	hr/w	9.476	12.142
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.010
Media	Radon Outdoors	0.0	58	Bq/m3	0.543	9.530
Consumption	OtherVeg-10year	0.0	120	g/d	16.082	293
Media	Pb-210 in Air	0.0	79	Bq/m3	0.00011	0.0012
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0033
Consumption	SoilDust-10year	0.0	155	g/d	0.0067	0.256
Media	Gamma Outdoors	0.0	9	uR/h	5.216	7.034
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Consumption	Air-10year	0.0	23	m3/d	9.854	20.263
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Media	Th-230 in Water	0.0	57	Bq/L	0.00055	0.0095
Consumption	Fruit-10year	0.0	86	g/d	55.969	679
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Media	U-238 in SoilDust	0.0	19	Bq/g	0.0028	0.0052
Media	Ra-226 in SoilDust	0.0	54	Bq/g	0.0063	0.032
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141
Occupancy	Indoors-Winter-10year	0.0	8	hr/w	105	133
Media	Po-210 in Air	0.0	59	Bq/m3	2.83E-6	0.00006

Table B.3.14(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 15 year old in Zone 1

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00019	11.6	0.00019	0.00025	18
Radon	0.0012	75.2	0.00087	0.0035	104
Water	0.00021	12.5	0.00016	0.00054	84
Other	0.00001	0.7	8.69E-6	0.00003	76
Total	0.0016	100.0	0.0013	0.0038	79

Table B.3.14(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 15 year old in Zone 1

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pct Sample Value
Media	Radon Indoors	96.6	105	Bq/m3	15.376	24
Consumption	Water-15year	0.9	61	L/d	0.352	2.23
Occupancy	Indoors-Summer-15year	0.5	10	hr/w	87.366	11
Occupancy	Indoors-Winter-15year	0.4	12	hr/w	92.102	13
Consumption	OtherVeg-15year	0.2	111	g/d	18.583	37
Consumption	Air-15year	0.2	26	m3/d	10.124	23.00
Media	Pb-210 in Water	0.1	58	Bq/L	0.022	0.47
Media	Ra-226 in Water	0.1	59	Bq/L	0.0051	0.09
Occupancy	Outdoors-Winter-15year	0.1	11	hr/w	8.388	12.05
Media	Gamma Indoors	0.1	19	uR/h	3.391	6.40
Occupancy	Outdoors-Summer-15year	0.1	21	hr/w	12.816	25.73
Media	Po-210 in Water	0.0	58	Bq/L	0.00054	0.009
Consumption	SoilDust-15year	0.0	40	g/d	0.024	0.09
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.01
Consumption	Fruit-15year	0.0	93	g/d	49.023	66
Media	Radon Outdoors	0.0	58	Bq/m3	0.543	9.53
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Media	Pb-210 in Air	0.0	79	Bq/m3	0.00011	0.001
Consumption	RootVeg-15year	0.0	79	g/d	60.447	58
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008
Media	Th-230 in Water	0.0	57	Bq/L	0.00055	0.009
Media	Ra-226 in SoilDust	0.0	54	Bq/g	0.0063	0.03
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.01
Media	U-238 in SoilDust	0.0	19	Bq/g	0.0028	0.005
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Media	Gamma Outdoors	0.0	9	uR/h	5.216	7.03
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.69
Media	Po-210 in Air	0.0	59	Bq/m3	2.83E-6	0.0000
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69

Table B.3.15(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for Adult in Zone 1

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00018	11.7	0.00018	0.00025	18
Radon	0.0013	81.0	0.00089	0.0035	104
Water	0.00011	6.8	0.00009	0.00026	79
Other	8.1E-6	0.5	6.44E-6	0.00002	76
Total	0.0016	100.0	0.0012	0.0038	84

Table B.3.15(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for Adult in Zone 1

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	97.0	105	Bq/m3	15.376	244
Occupancy	Indoors-Summer-Adult	1.0	11	hr/w	88.057	127
Consumption	Water-Adult	0.3	54	L/d	0.585	2.979
Consumption	Fruit-Adult	0.3	81	g/d	57.514	643
Consumption	SoilDust-Adult	0.2	38	g/d	0.024	0.096
Media	Ra-226 in Water	0.1	59	Bq/L	0.0051	0.095
Occupancy	Indoors-Winter-Adult	0.1	12	hr/w	92.276	132
Media	Gamma Indoors	0.1	19	uR/h	3.391	6.405
Occupancy	Outdoors-Winter-Adult	0.1	11	hr/w	8.350	12.036
Consumption	RootVeg-Adult	0.0	81	g/d	47.751	452
Media	Po-210 in Water	0.0	58	Bq/L	0.00054	0.0095
Occupancy	Outdoors-Summer-Adult	0.0	12	hr/w	12.493	18.048
Consumption	OtherVeg-Adult	0.0	96	g/d	27.887	366
Media	Pb-210 in Water	0.0	58	Bq/L	0.022	0.475
Media	Radon Outdoors	0.0	58	Bq/m3	0.543	9.530
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.010
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0033
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Media	Pb-210 in Air	0.0	79	Bq/m3	0.00011	0.0012
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Media	Po-210 in Air	0.0	59	Bq/m3	2.83E-6	0.00006
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Media	Th-230 in Water	0.0	57	Bq/L	0.00055	0.0095
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Media	U-238 in SoilDust	0.0	19	Bq/g	0.0028	0.0052
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141
Consumption	Air-Adult	0.0	25	m3/d	10.283	23.320
Media	Gamma Outdoors	0.0	9	uR/h	5.216	7.034
Media	Ra-226 in SoilDust	0.0	54	Bq/g	0.0063	0.032

Table B.3.16(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 1 year old in Zone 2

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00026	20.4	0.00026	0.00031	12
Radon	0.00077	60.6	0.00059	0.0020	82
Water	0.00022	17.0	0.00016	0.00058	92
Other	0.00002	1.9	0.00002	0.00006	68
Total	0.0013	100.0	0.0011	0.0025	52

Table B.3.16(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 1 year old in Zone 2

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pct Sample Value
Media	Radon Indoors	89.4	84	Bq/m3	10.650	11
Consumption	Water-01year	5.2	65	L/d	0.188	1.32
Media	Pb-210 in Water	3.0	59	Bq/L	0.022	0.47
Media	Gamma Indoors	0.6	14	uR/h	3.659	5.72
Media	U-238 in Water	0.1	41	Bq/L	0.0018	0.01
Consumption	Air-01year	0.1	28	m3/d	5.705	14.38
Media	Th-230 in Water	0.1	59	Bq/L	0.00041	0.009
Consumption	OtherVeg-01year	0.0	104	g/d	9.739	19
Media	Pb-210 in Air	0.0	74	Bq/m3	0.00015	0.001
Consumption	SoilDust-01year	0.0	150	g/d	0.0070	0.27
Media	Ra-226 in Water	0.0	59	Bq/L	0.0054	0.09
Consumption	Fruit-01year	0.0	78	g/d	58.487	58
Consumption	RootVeg-01year	0.0	85	g/d	24.067	25
Media	Radon Outdoors	0.0	57	Bq/m3	0.511	9.57
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.69
Media	Ra-226 in SoilDust	0.0	33	Bq/g	0.010	0.03
Media	Po-210 in Air	0.0	59	Bq/m3	9.31E-6	0.0000
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Media	Po-210 in Water	0.0	60	Bq/L	0.00048	0.009
Media	Gamma Outdoors	0.0	8	uR/h	5.072	6.69
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.01
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Media	U-238 in SoilDust	0.0	24	Bq/g	0.0027	0.005
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.38

Table B.3.17(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 5 year old in Zone 2

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00023	20.3	0.00023	0.00028	13
Radon	0.00071	62.6	0.00055	0.0018	81
Water	0.00017	15.3	0.00014	0.00043	78
Other	0.00002	1.8	0.00002	0.00005	69
Total	0.0011	100.0	0.00098	0.0022	53

Table B.3.17(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 5 year old in Zone 2

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	93.0	84	Bq/m3	10.650	117
Media	Pb-210 in Water	2.6	59	Bq/L	0.022	0.474
Consumption	Water-05year	1.8	49	L/d	0.333	1.539
Media	Gamma Indoors	0.5	14	uR/h	3.659	5.721
Occupancy	Indoors-Summer-05year	0.3	8	hr/w	99.552	127
Occupancy	Indoors-Winter-05year	0.2	8	hr/w	105	133
Consumption	SoilDust-05year	0.1	152	g/d	0.0072	0.256
Media	U-238 in Water	0.1	41	Bq/L	0.0018	0.010
Occupancy	Outdoors-Summer-05year	0.1	17	hr/w	14.716	25.582
Occupancy	Outdoors-Winter-05year	0.1	8	hr/w	9.449	12.128
Media	Pb-210 in Air	0.1	74	Bq/m3	0.00015	0.0014
Consumption	RootVeg-05year	0.1	86	g/d	33.149	426
Media	Th-230 in Water	0.0	59	Bq/L	0.00041	0.0095
Media	Radon Outdoors	0.0	57	Bq/m3	0.511	9.579
Consumption	Fruit-05year	0.0	90	g/d	56.995	675
Media	Ra-226 in Water	0.0	59	Bq/L	0.0054	0.095
Media	Po-210 in Water	0.0	60	Bq/L	0.00048	0.0094
Consumption	OtherVeg-05year	0.0	115	g/d	15.033	273
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Media	Gamma Outdoors	0.0	8	uR/h	5.072	6.698
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Media	Ra-226 in SoilDust	0.0	33	Bq/g	0.010	0.030
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0033
Media	U-238 in SoilDust	0.0	24	Bq/g	0.0027	0.0058
Consumption	Air-05year	0.0	22	m3/d	9.915	20.027
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Media	Po-210 in Air	0.0	59	Bq/m3	9.31E-6	0.00006
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696

Table B.3.18(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 10 year old in Zone 2

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00021	19.4	0.00021	0.00026	13
Radon	0.00071	65.5	0.00054	0.0018	82
Water	0.00015	13.8	0.00012	0.00037	77
Other	0.00001	1.3	0.00001	0.00003	68
Total	0.0011	100.0	0.00092	0.0022	54

Table B.3.18(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 10 year old in Zone 2

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pct Sample Value
Media	Radon Indoors	95.0	84	Bq/m3	10.650	11
Media	Pb-210 in Water	1.9	59	Bq/L	0.022	0.47
Consumption	Water-10year	1.0	49	L/d	0.327	1.51
Media	Gamma Indoors	0.5	14	uR/h	3.659	5.72
Occupancy	Indoors-Summer-10year	0.3	8	hr/w	99.571	12
Media	U-238 in Water	0.1	41	Bq/L	0.0018	0.01
Media	Th-230 in Water	0.1	59	Bq/L	0.00041	0.009
Occupancy	Indoors-Winter-10year	0.1	8	hr/w	105	13
Consumption	SoilDust-10year	0.1	155	g/d	0.0067	0.25
Media	Radon Outdoors	0.0	57	Bq/m3	0.511	9.57
Media	Po-210 in Water	0.0	60	Bq/L	0.00048	0.009
Media	Pb-210 in Air	0.0	74	Bq/m3	0.00015	0.001
Occupancy	Outdoors-Winter-10year	0.0	8	hr/w	9.476	12.14
Consumption	OtherVeg-10year	0.0	120	g/d	16.082	29
Media	Ra-226 in Water	0.0	59	Bq/L	0.0054	0.09
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.01
Media	Gamma Outdoors	0.0	8	uR/h	5.072	6.69
Consumption	RootVeg-10year	0.0	90	g/d	33.368	42
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14
Media	U-238 in SoilDust	0.0	24	Bq/g	0.0027	0.005
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Media	Ra-226 in SoilDust	0.0	33	Bq/g	0.010	0.03
Consumption	Air-10year	0.0	23	m3/d	9.854	20.26
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.69
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Media	Po-210 in Air	0.0	59	Bq/m3	9.31E-6	0.0000
Occupancy	Outdoors-Summer-10year	0.0	18	hr/w	14.554	25.80
Consumption	Fruit-10year	0.0	86	g/d	55.969	67
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69

Table B.3.19(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 15 year old in Zone 2

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00019	17.6	0.00019	0.00023	14
Radon	0.00066	62.1	0.00051	0.0017	82
Water	0.0002	19.0	0.00016	0.00052	83
Other	0.00001	1.2	0.00001	0.00003	72
Total	0.0011	100.0	0.00091	0.0021	53

Table B.3.19(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 15 year old in Zone 2

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	88.7	84	Bq/m3	10.650	117
Consumption	Water-15year	4.1	61	L/d	0.352	2.238
Media	Pb-210 in Water	3.3	59	Bq/L	0.022	0.474
Occupancy	Indoors-Summer-15year	0.9	10	hr/w	87.366	119
Occupancy	Indoors-Winter-15year	0.5	12	hr/w	92.102	133
Media	Gamma Indoors	0.4	14	uR/h	3.659	5.721
Consumption	Air-15year	0.1	26	m3/d	10.124	23.006
Media	U-238 in Water	0.1	41	Bq/L	0.0018	0.010
Media	Radon Outdoors	0.1	57	Bq/m3	0.511	9.579
Media	Th-230 in Water	0.1	59	Bq/L	0.00041	0.0095
Occupancy	Outdoors-Summer-15year	0.0	21	hr/w	12.816	25.731
Consumption	Fruit-15year	0.0	93	g/d	49.023	664
Media	Pb-210 in Air	0.0	74	Bq/m3	0.00015	0.0014
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141
Media	Ra-226 in Water	0.0	59	Bq/L	0.0054	0.095
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Media	Ra-226 in SoilDust	0.0	33	Bq/g	0.010	0.030
Consumption	OtherVeg-15year	0.0	111	g/d	18.583	372
Occupancy	Outdoors-Winter-15year	0.0	11	hr/w	8.388	12.056
Media	Gamma Outdoors	0.0	8	uR/h	5.072	6.698
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0033
Consumption	RootVeg-15year	0.0	79	g/d	60.447	580
Media	Po-210 in Water	0.0	60	Bq/L	0.00048	0.0094
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Consumption	SoilDust-15year	0.0	40	g/d	0.024	0.096
Media	Po-210 in Air	0.0	59	Bq/m3	9.31E-6	0.00006
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696
Media	U-238 in SoilDust	0.0	24	Bq/g	0.0027	0.0058

Table B.3.20(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for Adult in Zone 2

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00018	18.6	0.00018	0.00023	14
Radon	0.00067	69.4	0.00052	0.0017	82
Water	0.00011	11.0	0.00009	0.00027	83
Other	9.77E-6	1.0	7.97E-6	0.00002	68
Total	0.00097	100.0	0.00081	0.0021	58

Table B.3.20(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for Adult in Zone 2

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pc Sample Valu
Media	Radon Indoors	94.5	84	Bq/m3	10.650	11
Media	Pb-210 in Water	1.2	59	Bq/L	0.022	0.47
Occupancy	Indoors-Summer-Adult	1.1	11	hr/w	88.057	12
Consumption	Water-Adult	0.8	54	L/d	0.585	2.97
Media	Gamma Indoors	0.4	14	uR/h	3.659	5.72
Occupancy	Indoors-Winter-Adult	0.4	12	hr/w	92.276	13
Consumption	OtherVeg-Adult	0.1	96	g/d	27.887	36
Media	U-238 in Water	0.1	41	Bq/L	0.0018	0.01
Consumption	Air-Adult	0.1	25	m3/d	10.283	23.32
Media	Th-230 in Water	0.1	59	Bq/L	0.00041	0.009
Consumption	Fruit-Adult	0.1	81	g/d	57.514	64
Consumption	SoilDust-Adult	0.0	38	g/d	0.024	0.09
Media	Radon Outdoors	0.0	57	Bq/m3	0.511	9.57
Media	Ra-226 in Water	0.0	59	Bq/L	0.0054	0.09
Consumption	RootVeg-Adult	0.0	81	g/d	47.751	45
Media	Po-210 in Water	0.0	60	Bq/L	0.00048	0.009
Media	Pb-210 in Air	0.0	74	Bq/m3	0.00015	0.001
Occupancy	Outdoors-Winter-Adult	0.0	11	hr/w	8.350	12.03
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.69
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.01
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008
Occupancy	Outdoors-Summer-Adult	0.0	12	hr/w	12.493	18.04
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Media	Po-210 in Air	0.0	59	Bq/m3	9.31E-6	0.0000
Media	U-238 in SoilDust	0.0	24	Bq/g	0.0027	0.005
Media	Ra-226 in SoilDust	0.0	33	Bq/g	0.010	0.03
Media	Gamma Outdoors	0.0	8	uR/h	5.072	6.69
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69

Table B.3.21(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 1 year old in Zone 3

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00029	21.4	0.00029	0.00037	17
Radon	0.00083	60.9	0.00062	0.0022	86
Water	0.00022	15.9	0.00017	0.00057	91
Other	0.00003	1.9	0.00002	0.00006	70
Total	0.0014	100.0	0.0012	0.0028	55

Table B.3.21(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 1 year old in Zone 3

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	91.9	88	Bq/m3	9.823	132
Consumption	Water-01year	3.4	65	L/d	0.188	1.329
Media	Pb-210 in Water	2.5	58	Bq/L	0.023	0.477
Media	Gamma Indoors	0.4	20	uR/h	3.623	6.801
Consumption	SoilDust-01year	0.2	150	g/d	0.0070	0.270
Media	Po-210 in Water	0.2	57	Bq/L	0.0005	0.0096
Consumption	Air-01year	0.1	28	m3/d	5.705	14.385
Media	U-238 in Water	0.1	41	Bq/L	0.0020	0.010
Media	Pb-210 in Air	0.0	76	Bq/m3	0.00017	0.0015
Media	Ra-226 in Water	0.0	58	Bq/L	0.0052	0.096
Consumption	RootVeg-01year	0.0	85	g/d	24.067	259
Consumption	Fruit-01year	0.0	78	g/d	58.487	587
Media	Th-230 in Water	0.0	57	Bq/L	0.00049	0.0095
Media	Radon Outdoors	0.0	56	Bq/m3	0.562	9.534
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141
Consumption	OtherVeg-01year	0.0	104	g/d	9.739	192
Media	Ra-226 in SoilDust	0.0	33	Bq/g	0.0098	0.029
Media	Gamma Outdoors	0.0	7	uR/h	6.184	7.765
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0033
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696
Media	U-238 in SoilDust	0.0	40	Bq/g	0.0024	0.0085
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Media	Po-210 in Air	0.0	69	Bq/m3	7.35E-6	0.00006
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.380

Table B.3.22(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 5 year old in Zone 3

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00026	21.2	0.00026	0.00034	17
Radon	0.00077	62.8	0.00057	0.0021	87
Water	0.00018	14.4	0.00015	0.00042	77
Other	0.00002	1.7	0.00002	0.00005	69
Total	0.0012	100.0	0.0010	0.0026	56

Table B.3.22(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 5 year old in Zone 3

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pc Sample Valu
Media	Radon Indoors	94.0	88	Bq/m3	9.823	13
Media	Pb-210 in Water	2.2	58	Bq/L	0.023	0.47
Consumption	Water-05year	1.2	49	L/d	0.333	1.53
Occupancy	Indoors-Summer-05year	0.6	8	hr/w	99.552	12
Media	Gamma Indoors	0.4	20	uR/h	3.623	6.80
Occupancy	Indoors-Winter-05year	0.2	8	hr/w	105	13
Media	Po-210 in Water	0.1	57	Bq/L	0.0005	0.009
Media	U-238 in Water	0.1	41	Bq/L	0.0020	0.01
Consumption	OtherVeg-05year	0.1	115	g/d	15.033	27
Consumption	Air-05year	0.1	22	m3/d	9.915	20.02
Occupancy	Outdoors-Summer-05year	0.0	17	hr/w	14.716	25.58
Media	Ra-226 in Water	0.0	58	Bq/L	0.0052	0.09
Media	Pb-210 in Air	0.0	76	Bq/m3	0.00017	0.001
Media	Radon Outdoors	0.0	56	Bq/m3	0.562	9.53
Consumption	RootVeg-05year	0.0	86	g/d	33.149	42
Media	Th-230 in Water	0.0	57	Bq/L	0.00049	0.009
Occupancy	Outdoors-Winter-05year	0.0	8	hr/w	9.449	12.12
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Consumption	Fruit-05year	0.0	90	g/d	56.995	67
Media	Gamma Outdoors	0.0	7	uR/h	6.184	7.76
Consumption	SoilDust-05year	0.0	152	g/d	0.0072	0.25
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008
Media	Po-210 in Air	0.0	69	Bq/m3	7.35E-6	0.0000
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.69
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Media	Ra-226 in SoilDust	0.0	33	Bq/g	0.0098	0.02
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.01
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69
Media	U-238 in SoilDust	0.0	40	Bq/g	0.0024	0.008
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14

Table B.3.23(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 10 year old in Zone 3

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00024	20.2	0.00023	0.00031	17
Radon	0.00077	65.4	0.00057	0.0020	86
Water	0.00015	13.2	0.00013	0.00038	78
Other	0.00001	1.3	0.00001	0.00003	72
Total	0.0012	100.0	0.00098	0.0024	57

Table B.3.23(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 10 year old in Zone 3

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	95.2	88	Bq/m3	9.823	132
Media	Pb-210 in Water	1.6	58	Bq/L	0.023	0.477
Consumption	Water-10year	1.0	49	L/d	0.327	1.518
Occupancy	Indoors-Winter-10year	0.4	8	hr/w	105	133
Media	Gamma Indoors	0.3	20	uR/h	3.623	6.801
Consumption	OtherVeg-10year	0.2	120	g/d	16.082	293
Media	U-238 in Water	0.1	41	Bq/L	0.0020	0.010
Media	Po-210 in Water	0.1	57	Bq/L	0.0005	0.0096
Occupancy	Indoors-Summer-10year	0.1	8	hr/w	99.571	127
Consumption	RootVeg-10year	0.1	90	g/d	33.368	424
Occupancy	Outdoors-Summer-10year	0.0	18	hr/w	14.554	25.803
Consumption	Fruit-10year	0.0	86	g/d	55.969	679
Media	Radon Outdoors	0.0	56	Bq/m3	0.562	9.534
Consumption	Air-10year	0.0	23	m3/d	9.854	20.263
Media	Pb-210 in Air	0.0	76	Bq/m3	0.00017	0.0015
Media	Ra-226 in Water	0.0	58	Bq/L	0.0052	0.096
Consumption	SoilDust-10year	0.0	155	g/d	0.0067	0.256
Occupancy	Outdoors-Winter-10year	0.0	8	hr/w	9.476	12.142
Media	Th-230 in Water	0.0	57	Bq/L	0.00049	0.0095
Media	Gamma Outdoors	0.0	7	uR/h	6.184	7.765
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0033
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Media	Po-210 in Air	0.0	69	Bq/m3	7.35E-6	0.00006
Media	Ra-226 in SoilDust	0.0	33	Bq/g	0.0098	0.029
Media	U-238 in SoilDust	0.0	40	Bq/g	0.0024	0.0085
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696

Table B.3.24(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 15 year old in Zone 3

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00021	18.4	0.00021	0.00028	18
Radon	0.00071	62.1	0.00053	0.0019	87
Water	0.00021	18.3	0.00016	0.00057	86
Other	0.00001	1.2	0.00001	0.00003	73
Total	0.0011	100.0	0.00097	0.0023	56

Table B.3.24(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 15 year old in Zone 3

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pc Sample Valu
Media	Radon Indoors	89.2	88	Bq/m3	9.823	13.
Consumption	Water-15year	4.2	61	L/d	0.352	2.23
Media	Pb-210 in Water	2.7	58	Bq/L	0.023	0.47
Occupancy	Indoors-Summer-15year	0.6	10	hr/w	87.366	11
Occupancy	Indoors-Winter-15year	0.5	12	hr/w	92.102	13
Media	Gamma Indoors	0.2	20	uR/h	3.623	6.80
Occupancy	Outdoors-Summer-15year	0.2	21	hr/w	12.816	25.73
Media	U-238 in Water	0.2	41	Bq/L	0.0020	0.01
Consumption	SoilDust-15year	0.2	40	g/d	0.024	0.09
Consumption	Fruit-15year	0.1	93	g/d	49.023	66
Consumption	Air-15year	0.1	26	m3/d	10.124	23.00
Occupancy	Outdoors-Winter-15year	0.1	11	hr/w	8.388	12.05
Media	Po-210 in Water	0.1	57	Bq/L	0.0005	0.009
Consumption	RootVeg-15year	0.1	79	g/d	60.447	58
Consumption	OtherVeg-15year	0.0	111	g/d	18.583	37
Media	Radon Outdoors	0.0	56	Bq/m3	0.562	9.53
Media	Pb-210 in Air	0.0	76	Bq/m3	0.00017	0.001
Media	Gamma Outdoors	0.0	7	uR/h	6.184	7.76
Media	U-238 in SoilDust	0.0	40	Bq/g	0.0024	0.008
Media	Ra-226 in Water	0.0	58	Bq/L	0.0052	0.09
Media	Th-230 in Water	0.0	57	Bq/L	0.00049	0.009
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.69
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Media	Po-210 in Air	0.0	69	Bq/m3	7.35E-6	0.0000
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.01
Media	Ra-226 in SoilDust	0.0	33	Bq/g	0.0098	0.02
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008

Table B.3.25(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for Adult in Zone 3

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.0002	19.3	0.0002	0.00027	18
Radon	0.00072	69.4	0.00054	0.0019	86
Water	0.00011	10.4	0.00009	0.00027	78
Other	0.00001	1.0	8.01E-6	0.00002	79
Total	0.0010	100.0	0.00086	0.0022	61

Table B.3.25(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for Adult in Zone 3

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	94.5	88	Bq/m3	9.823	132
Consumption	Water-Adult	1.3	54	L/d	0.585	2.979
Media	Pb-210 in Water	1.0	58	Bq/L	0.023	0.477
Occupancy	Indoors-Summer-Adult	0.7	11	hr/w	88.057	127
Occupancy	Indoors-Winter-Adult	0.5	12	hr/w	92.276	132
Media	Gamma Indoors	0.2	20	uR/h	3.623	6.801
Consumption	Air-Adult	0.2	25	m3/d	10.283	23.320
Media	Po-210 in Water	0.1	57	Bq/L	0.0005	0.0096
Media	U-238 in Water	0.1	41	Bq/L	0.0020	0.010
Consumption	SoilDust-Adult	0.1	38	g/d	0.024	0.096
Media	Ra-226 in Water	0.0	58	Bq/L	0.0052	0.096
Consumption	OtherVeg-Adult	0.0	96	g/d	27.887	366
Occupancy	Outdoors-Winter-Adult	0.0	11	hr/w	8.350	12.036
Consumption	Fruit-Adult	0.0	81	g/d	57.514	643
Media	Radon Outdoors	0.0	56	Bq/m3	0.562	9.534
Media	Pb-210 in Air	0.0	76	Bq/m3	0.00017	0.0015
Media	Th-230 in Water	0.0	57	Bq/L	0.00049	0.0095
Media	Gamma Outdoors	0.0	7	uR/h	6.184	7.765
Consumption	RootVeg-Adult	0.0	81	g/d	47.751	452
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Media	Ra-226 in SoilDust	0.0	33	Bq/g	0.0098	0.029
Media	U-238 in SoilDust	0.0	40	Bq/g	0.0024	0.0085
Occupancy	Outdoors-Summer-Adult	0.0	12	hr/w	12.493	18.048
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0033
Media	Po-210 in Air	0.0	69	Bq/m3	7.35E-6	0.00006
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141

Table B.3.26(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 1 year old in Zone 4

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00033	10.3	0.00033	0.00036	4
Radon	0.0027	82.2	0.0020	0.0067	83
Water	0.00022	6.7	0.00016	0.0006	92
Other	0.00003	0.8	0.00002	0.00006	81
Total	0.0032	100.0	0.0026	0.0074	68

Table B.3.26(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 1 year old in Zone 4

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pct Sample Value
Media	Radon Indoors	98.0	84	Bq/m3	35.510	40
Consumption	Water-01year	0.6	65	L/d	0.188	1.32
Media	Pb-210 in Water	0.4	59	Bq/L	0.023	0.47
Media	Po-210 in Water	0.2	57	Bq/L	0.00054	0.009
Media	Gamma Indoors	0.2	5	uR/h	5.250	6.17
Consumption	Air-01year	0.1	28	m3/d	5.705	14.38
Media	Ra-226 in Water	0.1	58	Bq/L	0.0049	0.09
Media	Th-230 in Water	0.0	59	Bq/L	0.00044	0.009
Media	Radon Outdoors	0.0	89	Bq/m3	3.042	35.05
Consumption	RootVeg-01year	0.0	85	g/d	24.067	25
Media	Pb-210 in Air	0.0	93	Bq/m3	0.00015	0.001
Consumption	Fruit-01year	0.0	78	g/d	58.487	58
Consumption	OtherVeg-01year	0.0	104	g/d	9.739	19
Media	Gamma Outdoors	0.0	11	uR/h	7.380	10.71
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.01
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Media	Ra-226 in SoilDust	0.0	43	Bq/g	0.0074	0.02
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.69
Consumption	SoilDust-01year	0.0	150	g/d	0.0070	0.27
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Media	Po-210 in Air	0.0	58	Bq/m3	2.42E-6	0.0000
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.01
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69
Media	U-238 in SoilDust	0.0	75	Bq/g	0.0019	0.01
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.38

Table B.3.27(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 5 year old in Zone 4

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.0003	10.1	0.00029	0.00033	7
Radon	0.0024	83.3	0.0019	0.0062	82
Water	0.00017	5.9	0.00014	0.00042	77
Other	0.00002	0.7	0.00002	0.00006	85
Total	0.0029	100.0	0.0024	0.0067	69

Table B.3.27(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 5 year old in Zone 4

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	98.2	84	Bq/m3	35.510	401
Media	Pb-210 in Water	0.3	59	Bq/L	0.023	0.476
Media	Po-210 in Water	0.3	57	Bq/L	0.00054	0.0094
Media	Gamma Indoors	0.2	5	uR/h	5.250	6.171
Occupancy	Outdoors-Summer-05year	0.2	17	hr/w	14.716	25.582
Occupancy	Outdoors-Winter-05year	0.1	8	hr/w	9.449	12.128
Media	Ra-226 in Water	0.1	58	Bq/L	0.0049	0.095
Occupancy	Indoors-Summer-05year	0.1	8	hr/w	99.552	127
Consumption	SoilDust-05year	0.1	152	g/d	0.0072	0.256
Media	Th-230 in Water	0.1	59	Bq/L	0.00044	0.0095
Media	Radon Outdoors	0.0	89	Bq/m3	3.042	35.051
Consumption	OtherVeg-05year	0.0	115	g/d	15.033	273
Occupancy	Indoors-Winter-05year	0.0	8	hr/w	105	133
Consumption	Air-05year	0.0	22	m3/d	9.915	20.027
Consumption	RootVeg-05year	0.0	86	g/d	33.149	426
Consumption	Fruit-05year	0.0	90	g/d	56.995	675
Media	Pb-210 in Air	0.0	93	Bq/m3	0.00015	0.0018
Consumption	Water-05year	0.0	49	L/d	0.333	1.539
Media	Gamma Outdoors	0.0	11	uR/h	7.380	10.713
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.011
Media	Ra-226 in SoilDust	0.0	43	Bq/g	0.0074	0.029
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0033
Media	Po-210 in Air	0.0	58	Bq/m3	2.42E-6	0.00004
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Media	U-238 in SoilDust	0.0	75	Bq/g	0.0019	0.018
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087

Table B.3.28(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 10 year old in Zone 4

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00027	9.4	0.00027	0.0003	7
Radon	0.0025	84.9	0.0019	0.0062	83
Water	0.00015	5.2	0.00013	0.00035	74
Other	0.00002	0.5	0.00001	0.00004	86
Total	0.0029	100.0	0.0023	0.0067	71

Table B.3.28(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 10 year old in Zone 4

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pct Sampled Value
Media	Radon Indoors	97.7	84	Bq/m3	35.510	401
Occupancy	Indoors-Summer-10year	0.4	8	hr/w	99.571	127
Media	Gamma Indoors	0.2	5	uR/h	5.250	6.171
Media	Po-210 in Water	0.2	57	Bq/L	0.00054	0.0094
Media	Pb-210 in Water	0.2	59	Bq/L	0.023	0.476
Consumption	Fruit-10year	0.2	86	g/d	55.969	679
Occupancy	Indoors-Winter-10year	0.2	8	hr/w	105	133
Media	Ra-226 in Water	0.1	58	Bq/L	0.0049	0.095
Consumption	Air-10year	0.1	23	m3/d	9.854	20.263
Occupancy	Outdoors-Summer-10year	0.1	18	hr/w	14.554	25.803
Media	Radon Outdoors	0.1	89	Bq/m3	3.042	35.051
Media	Th-230 in Water	0.0	59	Bq/L	0.00044	0.0095
Consumption	RootVeg-10year	0.0	90	g/d	33.368	424
Consumption	Water-10year	0.0	49	L/d	0.327	1.518
Occupancy	Outdoors-Winter-10year	0.0	8	hr/w	9.476	12.142
Consumption	SoilDust-10year	0.0	155	g/d	0.0067	0.256
Consumption	OtherVeg-10year	0.0	120	g/d	16.082	293
Media	Pb-210 in Air	0.0	93	Bq/m3	0.00015	0.0018
Media	Gamma Outdoors	0.0	11	uR/h	7.380	10.713
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696
Media	U-238 in SoilDust	0.0	75	Bq/g	0.0019	0.018
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Media	Po-210 in Air	0.0	58	Bq/m3	2.42E-6	0.00004
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Media	Ra-226 in SoilDust	0.0	43	Bq/g	0.0074	0.029
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0033
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.011
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011

Table B.3.29(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for 15 year old in Zone 4

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00024	8.8	0.00024	0.00027	8
Radon	0.0023	83.1	0.0017	0.0058	84
Water	0.00021	7.6	0.00016	0.00055	88
Other	0.00001	0.5	0.00001	0.00003	81
Total	0.0027	100.0	0.0022	0.0062	70

Table B.3.29(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for 15 year old in Zone 4

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	96.2	84	Bq/m3	35.510	401
Consumption	Water-15year	0.8	61	L/d	0.352	2.238
Occupancy	Indoors-Summer-15year	0.7	10	hr/w	87.366	119
Media	Pb-210 in Water	0.4	59	Bq/L	0.023	0.476
Media	Po-210 in Water	0.3	57	Bq/L	0.00054	0.0094
Occupancy	Indoors-Winter-15year	0.2	12	hr/w	92.102	133
Media	Gamma Indoors	0.2	5	uR/h	5.250	6.171
Media	Ra-226 in Water	0.1	58	Bq/L	0.0049	0.095
Occupancy	Outdoors-Winter-15year	0.1	11	hr/w	8.388	12.056
Consumption	SoilDust-15year	0.1	40	g/d	0.024	0.096
Media	Th-230 in Water	0.1	59	Bq/L	0.00044	0.0095
Media	Radon Outdoors	0.1	89	Bq/m3	3.042	35.051
Consumption	RootVeg-15year	0.0	79	g/d	60.447	580
Consumption	OtherVeg-15year	0.0	111	g/d	18.583	372
Occupancy	Outdoors-Summer-15year	0.0	21	hr/w	12.816	25.731
Consumption	Fruit-15year	0.0	93	g/d	49.023	664
Media	Gamma Outdoors	0.0	11	uR/h	7.380	10.713
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.0092
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.011
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.011
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.0033
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.696
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.141
Media	Pb-210 in Air	0.0	93	Bq/m3	0.00015	0.0018
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.00087
Media	Po-210 in Air	0.0	58	Bq/m3	2.42E-6	0.00004
Consumption	Air-15year	0.0	26	m3/d	10.124	23.006
Media	U-238 in SoilDust	0.0	75	Bq/g	0.0019	0.018
Media	Ra-226 in SoilDust	0.0	43	Bq/g	0.0074	0.029

Table B.3.30(a)
Summary of Contributions to Annual Dose (Sv/y)
from All Radiological Sources for Adult in Zone 4

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00023	8.6	0.00023	0.00026	9
Radon	0.0023	87.0	0.0018	0.0060	84
Water	0.00011	4.0	0.00009	0.00027	78
Other	0.00001	0.4	8.01E-6	0.00003	86
Total	0.0027	100.0	0.0021	0.0063	73

Table B.3.30(b)
Summary of Variability of Annual Dose (Sv/y)
from All Radiological Sources for Adult in Zone 4

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pct Sample Value
Media	Radon Indoors	97.3	84	Bq/m3	35.510	40
Occupancy	Indoors-Summer-Adult	0.7	11	hr/w	88.057	12
Media	Po-210 in Water	0.2	57	Bq/L	0.00054	0.009
Media	Pb-210 in Water	0.2	59	Bq/L	0.023	0.47
Media	Gamma Indoors	0.2	5	uR/h	5.250	6.17
Consumption	Water-Adult	0.1	54	L/d	0.585	2.97
Occupancy	Indoors-Winter-Adult	0.1	12	hr/w	92.276	13
Media	Ra-226 in Water	0.1	58	Bq/L	0.0049	0.09
Consumption	SoilDust-Adult	0.1	38	g/d	0.024	0.09
Media	Th-230 in Water	0.1	59	Bq/L	0.00044	0.009
Consumption	Air-Adult	0.1	25	m3/d	10.283	23.32
Occupancy	Outdoors-Summer-Adult	0.0	12	hr/w	12.493	18.04
Media	Radon Outdoors	0.0	89	Bq/m3	3.042	35.05
Consumption	Fruit-Adult	0.0	81	g/d	57.514	64
Consumption	OtherVeg-Adult	0.0	96	g/d	27.887	36
Occupancy	Outdoors-Winter-Adult	0.0	11	hr/w	8.350	12.03
Media	Gamma Outdoors	0.0	11	uR/h	7.380	10.71
Consumption	RootVeg-Adult	0.0	81	g/d	47.751	45
Media	U-238 in SoilDust	0.0	75	Bq/g	0.0019	0.01
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69
Media	Ra-226 in SoilDust	0.0	43	Bq/g	0.0074	0.02
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.01
Media	Pb-210 in Air	0.0	93	Bq/m3	0.00015	0.001
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Media	Po-210 in Air	0.0	58	Bq/m3	2.42E-6	0.0000
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.69
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.01
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008

Table B.3.31(a)
Summary of Contributions to Lifetime Risk
from All Radiological Sources for All Age Groups in Deloro

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.0011	17.4	0.0011	0.0015	17
Radon	0.0047	70.5	0.0033	0.013	95
Water	0.00074	11.1	0.00067	0.0016	63
Other	0.00007	1.0	0.00006	0.00015	63
Total	0.0066	100.0	0.0052	0.015	67

Table B.3.31(b)
Summary of Variability of Lifetime Risk
from All Radiological Sources for All Age Groups in Deloro

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	94.6	96	Bq/m3	9.617	167
Media	Pb-210 in Water	1.5	59	Bq/L	0.022	0.475
Media	U-238 in Water	0.6	40	Bq/L	0.0019	0.010
Occupancy	Indoors-Summer-Adult	0.3	11	hr/w	88.057	127
Occupancy	Indoors-Summer-15year	0.3	10	hr/w	87.366	119
Consumption	Fruit-05year	0.2	90	g/d	56.995	675
Consumption	Water-Adult	0.2	54	L/d	0.585	2.979
Occupancy	Indoors-Winter-Adult	0.2	12	hr/w	92.276	132
Consumption	OtherVeg-15year	0.2	111	g/d	18.583	372
Occupancy	Outdoors-Winter-Adult	0.1	11	hr/w	8.350	12.036
Consumption	Air-05year	0.1	22	m3/d	9.915	20.027
Occupancy	Outdoors-Winter-05year	0.1	8	hr/w	9.449	12.128
Consumption	Water-10year	0.1	49	L/d	0.327	1.518
Occupancy	Indoors-Winter-15year	0.1	12	hr/w	92.102	133
Consumption	OtherVeg-05year	0.1	115	g/d	15.033	273
Media	Ra-226 in Water	0.1	57	Bq/L	0.0056	0.096
Consumption	Fruit-15year	0.1	93	g/d	49.023	664
Occupancy	Outdoors-Summer-Adult	0.1	12	hr/w	12.493	18.048
Consumption	Air-01year	0.1	28	m3/d	5.705	14.385
Consumption	Water-15year	0.1	61	L/d	0.352	2.238
Consumption	SoilDust-05year	0.1	152	g/d	0.0072	0.256
Media	Radon Outdoors	0.0	75	Bq/m3	1.677	15.694
Consumption	Fruit-01year	0.0	78	g/d	58.487	587
Consumption	Air-10year	0.0	23	m3/d	9.854	20.263
Occupancy	Indoors-Winter-10year	0.0	8	hr/w	105	133
Occupancy	Outdoors-Winter-10year	0.0	8	hr/w	9.476	12.142
Consumption	Fruit-Adult	0.0	81	g/d	57.514	643
Consumption	OtherVeg-Adult	0.0	96	g/d	27.887	366
Consumption	Air-15year	0.0	26	m3/d	10.124	23.006
Media	Gamma Indoors	0.0	19	uR/h	3.649	6.631
Consumption	Water-01year	0.0	65	L/d	0.188	1.329
Occupancy	Outdoors-Summer-10year	0.0	18	hr/w	14.554	25.803
Consumption	RootVeg-01year	0.0	85	g/d	24.067	259
Consumption	OtherVeg-01year	0.0	104	g/d	9.739	192

Table B.3.31(b) - Cont'd
Summary of Variability of Lifetime Risk
from All Radiological Sources for All Age Groups in Deloro

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pc Sample Valu
Occupancy	Indoors-Summer-05year	0.0	8	hr/w	99.552	12
Occupancy	Outdoors-Summer-15year	0.0	21	hr/w	12.816	25.73
Consumption	RootVeg-15year	0.0	79	g/d	60.447	58
Consumption	RootVeg-05year	0.0	86	g/d	33.149	42
Consumption	SoilDust-Adult	0.0	38	g/d	0.024	0.09
Consumption	SoilDust-01year	0.0	150	g/d	0.0070	0.27
Media	Pb-210 in Air	0.0	74	Bq/m3	0.00016	0.001
Consumption	Water-05year	0.0	49	L/d	0.333	1.53
Occupancy	Indoors-Summer-10year	0.0	8	hr/w	99.571	12
Consumption	SoilDust-15year	0.0	40	g/d	0.024	0.09
Consumption	Air-Adult	0.0	25	m3/d	10.283	23.32
Media	Gamma Outdoors	0.0	13	uR/h	5.430	8.28
Media	Po-210 in Water	0.0	58	Bq/L	0.00049	0.009
Consumption	RootVeg-10year	0.0	90	g/d	33.368	42
Consumption	RootVeg-Adult	0.0	81	g/d	47.751	45
Consumption	OtherVeg-10year	0.0	120	g/d	16.082	29
Occupancy	Outdoors-Winter-15year	0.0	11	hr/w	8.388	12.05
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.01
Consumption	SoilDust-10year	0.0	155	g/d	0.0067	0.25
Occupancy	Indoors-Winter-05year	0.0	8	hr/w	105	13
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008
Media	Po-210 in Air	0.0	51	Bq/m3	9.76E-6	0.0000
Media	Th-230 in Water	0.0	59	Bq/L	0.00043	0.009
Consumption	Fruit-10year	0.0	86	g/d	55.969	67
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Occupancy	Outdoors-Summer-05year	0.0	17	hr/w	14.716	25.58
Media	Ra-226 in SoilDust	0.0	36	Bq/g	0.0092	0.02
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.69
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69
Media	U-238 in SoilDust	0.0	43	Bq/g	0.0022	0.008
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.38

Table B.3.32(a)
Summary of Contributions to Lifetime Risk
from All Radiological Sources for All Age Groups in Background

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00095	15.2	0.00095	0.0012	15
Radon	0.0044	71.2	0.0026	0.015	132
Water	0.00074	11.9	0.00069	0.0015	60
Other	0.0001	1.6	0.00009	0.00017	40
Total	0.0062	100.0	0.0044	0.016	94

Table B.3.32(b)
Summary of Variability of Lifetime Risk
from All Radiological Sources for All Age Groups in Background

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	96.1	138	Bq/m3	4.785	180
Consumption	OtherVeg-05year	0.5	115	g/d	15.033	273
Consumption	OtherVeg-10year	0.3	120	g/d	16.082	293
Consumption	Water-10year	0.3	49	L/d	0.327	1.518
Consumption	Fruit-01year	0.2	78	g/d	58.487	587
Media	Po-210 in Water	0.2	58	Bq/L	0.00049	0.0095
Occupancy	Indoors-Summer-Adult	0.2	11	hr/w	88.057	127
Consumption	Air-10year	0.2	23	m3/d	9.854	20.263
Consumption	Fruit-Adult	0.2	81	g/d	57.514	643
Consumption	SoilDust-05year	0.2	152	g/d	0.0072	0.256
Consumption	Air-Adult	0.1	25	m3/d	10.283	23.320
Media	Pb-210 in Water	0.1	58	Bq/L	0.025	0.474
Occupancy	Indoors-Winter-05year	0.1	8	hr/w	105	133
Consumption	RootVeg-15year	0.1	79	g/d	60.447	580
Occupancy	Indoors-Summer-05year	0.1	8	hr/w	99.552	127
Consumption	Air-01year	0.1	28	m3/d	5.705	14.385
Occupancy	Outdoors-Winter-Adult	0.1	11	hr/w	8.350	12.036
Occupancy	Indoors-Summer-15year	0.1	10	hr/w	87.366	119
Consumption	RootVeg-10year	0.1	90	g/d	33.368	424
Media	Gamma Indoors	0.1	16	uR/h	3.120	5.182
Consumption	Water-Adult	0.1	54	L/d	0.585	2.979
Occupancy	Outdoors-Summer-10year	0.1	18	hr/w	14.554	25.803
Consumption	SoilDust-Adult	0.0	38	g/d	0.024	0.096
Occupancy	Outdoors-Winter-10year	0.0	8	hr/w	9.476	12.142
Consumption	Fruit-10year	0.0	86	g/d	55.969	679
Consumption	RootVeg-Adult	0.0	81	g/d	47.751	452
Consumption	Water-05year	0.0	49	L/d	0.333	1.539
Occupancy	Outdoors-Winter-05year	0.0	8	hr/w	9.449	12.128
Consumption	SoilDust-01year	0.0	150	g/d	0.0070	0.270
Occupancy	Indoors-Winter-15year	0.0	12	hr/w	92.102	133
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.010
Occupancy	Outdoors-Summer-05year	0.0	17	hr/w	14.716	25.582
Consumption	Fruit-15year	0.0	93	g/d	49.023	664
Occupancy	Outdoors-Summer-15year	0.0	21	hr/w	12.816	25.731

Table B.3.32(b) - Cont'd
Summary of Variability of Lifetime Risk
from All Radiological Sources for All Age Groups in Background

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pc Sample Valu
Media	Ra-226 in Water	0.0	59	Bq/L	0.0053	0.09
Consumption	RootVeg-01year	0.0	85	g/d	24.067	25
Consumption	Water-01year	0.0	65	L/d	0.188	1.32
Occupancy	Indoors-Winter-10year	0.0	8	hr/w	105	13
Media	Radon Outdoors	0.0	26	Bq/m3	6.531	15.45
Consumption	OtherVeg-15year	0.0	111	g/d	18.583	37
Occupancy	Outdoors-Winter-15year	0.0	11	hr/w	8.388	12.05
Consumption	SoilDust-15year	0.0	40	g/d	0.024	0.09
Media	Th-230 in Water	0.0	57	Bq/L	0.00059	0.009
Media	Gamma Outdoors	0.0	26	uR/h	3.244	7.77
Consumption	Water-15year	0.0	61	L/d	0.352	2.23
Consumption	Fruit-05year	0.0	90	g/d	56.995	67
Occupancy	Outdoors-Summer-Adult	0.0	12	hr/w	12.493	18.04
Media	Pb-210 in Air	0.0	35	Bq/m3	0.0004	0.001
Consumption	SoilDust-10year	0.0	155	g/d	0.0067	0.25
Consumption	OtherVeg-01year	0.0	104	g/d	9.739	19
Consumption	Air-15year	0.0	26	m3/d	10.124	23.00
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.69
Occupancy	Indoors-Winter-Adult	0.0	12	hr/w	92.276	13
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Media	U-238 in SoilDust	0.0	136	Bq/g	0	0.93
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Media	Ra-226 in SoilDust	0.0	29	Bq/g	0.013	0.03
Consumption	OtherVeg-Adult	0.0	96	g/d	27.887	36
Consumption	RootVeg-05year	0.0	86	g/d	33.149	42
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.01
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Media	Po-210 in Air	0.0	34	Bq/m3	0.00004	0.0001
Consumption	Air-05year	0.0	22	m3/d	9.915	20.02
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008
Occupancy	Indoors-Summer-10year	0.0	8	hr/w	99.571	12
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.38

Table B.3.33(a)
Summary of Contributions to Lifetime Risk
from All Radiological Sources for All Age Groups in Zone 1

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.0011	12.2	0.0011	0.0014	17
Radon	0.0070	78.7	0.0050	0.019	103
Water	0.00074	8.4	0.00069	0.0016	61
Other	0.00006	0.7	0.00005	0.00013	68
Total	0.0088	100.0	0.0068	0.021	81

Table B.3.33(b)
Summary of Variability of Lifetime Risk
from All Radiological Sources for All Age Groups in Zone 1

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	96.5	105	Bq/m3	15.376	244
Occupancy	Indoors-Summer-Adult	0.4	11	hr/w	88.057	127
Consumption	Fruit-Adult	0.3	81	g/d	57.514	643
Consumption	RootVeg-10year	0.3	90	g/d	33.368	424
Consumption	Water-Adult	0.2	54	L/d	0.585	2.979
Occupancy	Indoors-Winter-05year	0.2	8	hr/w	105	133
Consumption	OtherVeg-15year	0.2	111	g/d	18.583	372
Consumption	Air-15year	0.2	26	m3/d	10.124	23.006
Occupancy	Outdoors-Winter-05year	0.2	8	hr/w	9.449	12.128
Consumption	RootVeg-05year	0.1	86	g/d	33.149	426
Media	Ra-226 in Water	0.1	59	Bq/L	0.0051	0.095
Occupancy	Outdoors-Winter-15year	0.1	11	hr/w	8.388	12.056
Consumption	SoilDust-Adult	0.1	38	g/d	0.024	0.096
Occupancy	Indoors-Winter-15year	0.1	12	hr/w	92.102	133
Media	Gamma Indoors	0.1	19	uR/h	3.391	6.405
Consumption	SoilDust-01year	0.1	150	g/d	0.0070	0.270
Occupancy	Outdoors-Summer-10year	0.1	18	hr/w	14.554	25.803
Media	Po-210 in Water	0.1	58	Bq/L	0.00054	0.0095
Consumption	RootVeg-Adult	0.1	81	g/d	47.751	452
Occupancy	Indoors-Winter-10year	0.0	8	hr/w	105	133
Consumption	Fruit-05year	0.0	90	g/d	56.995	675
Consumption	Water-05year	0.0	49	L/d	0.333	1.539
Media	Pb-210 in Water	0.0	58	Bq/L	0.022	0.475
Consumption	OtherVeg-01year	0.0	104	g/d	9.739	192
Occupancy	Outdoors-Summer-Adult	0.0	12	hr/w	12.493	18.048
Occupancy	Indoors-Summer-10year	0.0	8	hr/w	99.571	127
Consumption	Air-05year	0.0	22	m3/d	9.915	20.027
Occupancy	Outdoors-Winter-Adult	0.0	11	hr/w	8.350	12.036
Occupancy	Outdoors-Summer-05year	0.0	17	hr/w	14.716	25.582
Occupancy	Outdoors-Summer-15year	0.0	21	hr/w	12.816	25.731
Consumption	SoilDust-05year	0.0	152	g/d	0.0072	0.256
Occupancy	Indoors-Winter-Adult	0.0	12	hr/w	92.276	132
Occupancy	Outdoors-Winter-10year	0.0	8	hr/w	9.476	12.142
Consumption	Water-15year	0.0	61	L/d	0.352	2.238

Table B.3.33(b) - Cont'd
Summary of Variability of Lifetime Risk
from All Radiological Sources for All Age Groups in Zone 1

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pc Sample Valu
Occupancy	Indoors-Summer-05year	0.0	8	hr/w	99.552	12
Consumption	OtherVeg-Adult	0.0	96	g/d	27.887	36
Consumption	Fruit-01year	0.0	78	g/d	58.487	58
Consumption	Water-10year	0.0	49	L/d	0.327	1.51
Consumption	SoilDust-15year	0.0	40	g/d	0.024	0.09
Media	Radon Outdoors	0.0	58	Bq/m3	0.543	9.53
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.01
Occupancy	Indoors-Summer-15year	0.0	10	hr/w	87.366	11
Consumption	Air-01year	0.0	28	m3/d	5.705	14.38
Consumption	Air-Adult	0.0	25	m3/d	10.283	23.32
Consumption	RootVeg-15year	0.0	79	g/d	60.447	58
Consumption	RootVeg-01year	0.0	85	g/d	24.067	25
Consumption	OtherVeg-10year	0.0	120	g/d	16.082	29
Consumption	Water-01year	0.0	65	L/d	0.188	1.32
Consumption	Fruit-15year	0.0	93	g/d	49.023	66
Media	Th-230 in Water	0.0	57	Bq/L	0.00055	0.009
Consumption	OtherVeg-05year	0.0	115	g/d	15.033	27
Media	Pb-210 in Air	0.0	79	Bq/m3	0.00011	0.001
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.01
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.69
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Media	Po-210 in Air	0.0	59	Bq/m3	2.83E-6	0.00006
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69
Media	Gamma Outdoors	0.0	9	uR/h	5.216	7.03
Consumption	Air-10year	0.0	23	m3/d	9.854	20.26
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008
Consumption	SoilDust-10year	0.0	155	g/d	0.0067	0.25
Media	Ra-226 in SoilDust	0.0	54	Bq/g	0.0063	0.03
Consumption	Fruit-10year	0.0	86	g/d	55.969	67
Media	U-238 in SoilDust	0.0	19	Bq/g	0.0028	0.005
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.38

Table B.3.34(a)
Summary of Contributions to Lifetime Risk
from All Radiological Sources for All Age Groups in Zone 2

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.0011	19.0	0.0010	0.0013	13
Radon	0.0037	66.5	0.0028	0.0094	82
Water	0.00073	13.3	0.00067	0.0015	63
Other	0.00007	1.3	0.00006	0.00015	63
Total	0.0055	100.0	0.0047	0.011	55

Table B.3.34(b)
Summary of Variability of Lifetime Risk
from All Radiological Sources for All Age Groups in Zone 2

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	95.1	84	Bq/m3	10.650	117
Media	Pb-210 in Water	1.8	59	Bq/L	0.022	0.474
Media	Gamma Indoors	0.4	14	uR/h	3.659	5.721
Occupancy	Indoors-Summer-Adult	0.3	11	hr/w	88.057	127
Consumption	Water-Adult	0.2	54	L/d	0.585	2.979
Occupancy	Indoors-Winter-Adult	0.1	12	hr/w	92.276	132
Consumption	SoilDust-05year	0.1	152	g/d	0.0072	0.256
Consumption	Air-01year	0.1	28	m3/d	5.705	14.385
Consumption	Water-01year	0.1	65	L/d	0.188	1.329
Consumption	OtherVeg-Adult	0.1	96	g/d	27.887	366
Media	U-238 in Water	0.1	41	Bq/L	0.0018	0.010
Consumption	Air-Adult	0.1	25	m3/d	10.283	23.320
Consumption	Air-15year	0.1	26	m3/d	10.124	23.006
Consumption	SoilDust-10year	0.1	155	g/d	0.0067	0.256
Media	Th-230 in Water	0.1	59	Bq/L	0.00041	0.0095
Consumption	Fruit-Adult	0.1	81	g/d	57.514	643
Consumption	RootVeg-05year	0.1	86	g/d	33.149	426
Consumption	SoilDust-01year	0.1	150	g/d	0.0070	0.270
Occupancy	Indoors-Winter-15year	0.1	12	hr/w	92.102	133
Occupancy	Indoors-Summer-15year	0.1	10	hr/w	87.366	119
Consumption	OtherVeg-01year	0.1	104	g/d	9.739	192
Consumption	Fruit-15year	0.1	93	g/d	49.023	664
Occupancy	Outdoors-Winter-05year	0.0	8	hr/w	9.449	12.128
Consumption	Fruit-05year	0.0	90	g/d	56.995	675
Media	Radon Outdoors	0.0	57	Bq/m3	0.511	9.579
Consumption	SoilDust-Adult	0.0	38	g/d	0.024	0.096
Occupancy	Outdoors-Summer-05year	0.0	17	hr/w	14.716	25.582
Occupancy	Outdoors-Winter-15year	0.0	11	hr/w	8.388	12.056
Consumption	Water-05year	0.0	49	L/d	0.333	1.539
Consumption	RootVeg-01year	0.0	85	g/d	24.067	259
Consumption	Air-05year	0.0	22	m3/d	9.915	20.027
Consumption	Water-10year	0.0	49	L/d	0.327	1.518
Media	Pb-210 in Air	0.0	74	Bq/m3	0.00015	0.0014
Occupancy	Outdoors-Summer-10year	0.0	18	hr/w	14.554	25.803

Table B.3.34(b) - Cont'd
Summary of Variability of Lifetime Risk
from All Radiological Sources for All Age Groups in Zone 2

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pc Sample Valu
Consumption	SoilDust-15year	0.0	40	g/d	0.024	0.09
Consumption	RootVeg-Adult	0.0	81	g/d	47.751	45
Media	Po-210 in Water	0.0	60	Bq/L	0.00048	0.009
Media	Ra-226 in Water	0.0	59	Bq/L	0.0054	0.09
Occupancy	Outdoors-Summer-15year	0.0	21	hr/w	12.816	25.73
Occupancy	Indoors-Summer-05year	0.0	8	hr/w	99.552	12
Consumption	OtherVeg-05year	0.0	115	g/d	15.033	27
Consumption	OtherVeg-10year	0.0	120	g/d	16.082	29
Consumption	Water-15year	0.0	61	L/d	0.352	2.23
Consumption	Fruit-01year	0.0	78	g/d	58.487	58
Occupancy	Indoors-Winter-05year	0.0	8	hr/w	105	13
Occupancy	Outdoors-Winter-10year	0.0	8	hr/w	9.476	12.14
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.69
Consumption	RootVeg-10year	0.0	90	g/d	33.368	42
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14
Occupancy	Outdoors-Winter-Adult	0.0	11	hr/w	8.350	12.03
Occupancy	Indoors-Winter-10year	0.0	8	hr/w	105	13
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.01
Consumption	RootVeg-15year	0.0	79	g/d	60.447	58
Media	Gamma Outdoors	0.0	8	uR/h	5.072	6.69
Occupancy	Outdoors-Summer-Adult	0.0	12	hr/w	12.493	18.04
Consumption	Fruit-10year	0.0	86	g/d	55.969	67
Occupancy	Indoors-Summer-10year	0.0	8	hr/w	99.571	12
Media	Ra-226 in SoilDust	0.0	33	Bq/g	0.010	0.03
Consumption	OtherVeg-15year	0.0	111	g/d	18.583	37
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Media	U-238 in SoilDust	0.0	24	Bq/g	0.0027	0.005
Consumption	Air-10year	0.0	23	m3/d	9.854	20.26
Media	Po-210 in Air	0.0	59	Bq/m3	9.31E-6	0.0000
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.38

Table B.3.35(a)
Summary of Contributions to Lifetime Risk
from All Radiological Sources for All Age Groups in Zone 3

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.0012	19.8	0.0012	0.0015	17
Radon	0.0040	66.5	0.0030	0.011	86
Water	0.00075	12.5	0.00069	0.0016	61
Other	0.00007	1.2	0.00006	0.00016	68
Total	0.0060	100.0	0.0050	0.013	58

Table B.3.35(b)
Summary of Variability of Lifetime Risk
from All Radiological Sources for All Age Groups in Zone 3

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	93.8	88	Bq/m3	9.823	132
Media	Pb-210 in Water	1.4	58	Bq/L	0.023	0.477
Consumption	Water-Adult	0.7	54	L/d	0.585	2.979
Media	Gamma Indoors	0.3	20	uR/h	3.623	6.801
Consumption	SoilDust-01year	0.3	150	g/d	0.0070	0.270
Occupancy	Indoors-Winter-Adult	0.2	12	hr/w	92.276	132
Consumption	SoilDust-15year	0.2	40	g/d	0.024	0.096
Consumption	Fruit-15year	0.2	93	g/d	49.023	664
Occupancy	Indoors-Summer-Adult	0.2	11	hr/w	88.057	127
Consumption	Air-Adult	0.2	25	m3/d	10.283	23.320
Consumption	OtherVeg-10year	0.2	120	g/d	16.082	293
Media	U-238 in Water	0.2	41	Bq/L	0.0020	0.010
Occupancy	Outdoors-Winter-15year	0.2	11	hr/w	8.388	12.056
Occupancy	Outdoors-Summer-15year	0.1	21	hr/w	12.816	25.731
Consumption	SoilDust-Adult	0.1	38	g/d	0.024	0.096
Media	Po-210 in Water	0.1	57	Bq/L	0.0005	0.0096
Consumption	Air-15year	0.1	26	m3/d	10.124	23.006
Consumption	RootVeg-15year	0.1	79	g/d	60.447	580
Occupancy	Indoors-Winter-10year	0.1	8	hr/w	105	133
Occupancy	Indoors-Summer-10year	0.1	8	hr/w	99.571	127
Consumption	OtherVeg-05year	0.1	115	g/d	15.033	273
Occupancy	Indoors-Summer-05year	0.1	8	hr/w	99.552	127
Consumption	Air-01year	0.1	28	m3/d	5.705	14.385
Consumption	OtherVeg-15year	0.1	111	g/d	18.583	372
Consumption	Water-15year	0.0	61	L/d	0.352	2.238
Consumption	Air-10year	0.0	23	m3/d	9.854	20.263
Consumption	RootVeg-10year	0.0	90	g/d	33.368	424
Consumption	RootVeg-01year	0.0	85	g/d	24.067	259
Consumption	Fruit-10year	0.0	86	g/d	55.969	679
Consumption	SoilDust-10year	0.0	155	g/d	0.0067	0.256
Consumption	Air-05year	0.0	22	m3/d	9.915	20.027
Occupancy	Indoors-Winter-05year	0.0	8	hr/w	105	133
Occupancy	Indoors-Winter-15year	0.0	12	hr/w	92.102	133
Occupancy	Outdoors-Winter-Adult	0.0	11	hr/w	8.350	12.036

Table B.3.35(b) - Cont'd
Summary of Variability of Lifetime Risk
from All Radiological Sources for All Age Groups in Zone 3

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th P Sampl Val
Occupancy	Outdoors-Summer-10year	0.0	18	hr/w	14.554	25.8
Consumption	RootVeg-05year	0.0	86	g/d	33.149	4
Consumption	OtherVeg-Adult	0.0	96	g/d	27.887	3
Media	Radon Outdoors	0.0	56	Bq/m3	0.562	9.5
Media	Pb-210 in Air	0.0	76	Bq/m3	0.00017	0.00
Consumption	Fruit-Adult	0.0	81	g/d	57.514	6
Occupancy	Outdoors-Summer-05year	0.0	17	hr/w	14.716	25.5
Media	Ra-226 in Water	0.0	58	Bq/L	0.0052	0.0
Occupancy	Outdoors-Winter-10year	0.0	8	hr/w	9.476	12.1
Consumption	Water-01year	0.0	65	L/d	0.188	1.3
Consumption	Water-10year	0.0	49	L/d	0.327	1.5
Occupancy	Indoors-Summer-15year	0.0	10	hr/w	87.366	1
Consumption	OtherVeg-01year	0.0	104	g/d	9.739	1
Consumption	Fruit-05year	0.0	90	g/d	56.995	6
Occupancy	Outdoors-Winter-05year	0.0	8	hr/w	9.449	12.1
Media	Gamma Outdoors	0.0	7	uR/h	6.184	7.7
Consumption	RootVeg-Adult	0.0	81	g/d	47.751	4
Consumption	Fruit-01year	0.0	78	g/d	58.487	5
Media	Th-230 in Water	0.0	57	Bq/L	0.00049	0.00
Occupancy	Outdoors-Summer-Adult	0.0	12	hr/w	12.493	18.0
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.0
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.6
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.1
Media	Ra-226 in SoilDust	0.0	33	Bq/g	0.0098	0.0
Media	Po-210 in Air	0.0	69	Bq/m3	7.35E-6	0.000
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.6
Consumption	Water-05year	0.0	49	L/d	0.333	1.5
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.000
Consumption	SoilDust-05year	0.0	152	g/d	0.0072	0.2
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.0
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.00
Media	U-238 in SoilDust	0.0	40	Bq/g	0.0024	0.00
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.00
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.3

Table B.3.36(a)
Summary of Contributions to Lifetime Risk
from All Radiological Sources for All Age Groups in Zone 4

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.0013	9.1	0.0013	0.0015	6
Radon	0.013	85.5	0.0097	0.032	83
Water	0.00074	5.0	0.00068	0.0016	61
Other	0.00008	0.5	0.00006	0.00019	80
Total	0.015	100.0	0.012	0.035	71

Table B.3.36(b)
Summary of Variability of Lifetime Risk
from All Radiological Sources for All Age Groups in Zone 4

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pctl Sampled Value
Media	Radon Indoors	96.6	84	Bq/m3	35.510	401
Media	Po-210 in Water	0.3	57	Bq/L	0.00054	0.0094
Occupancy	Outdoors-Summer-05year	0.2	17	hr/w	14.716	25.582
Media	Gamma Indoors	0.2	5	uR/h	5.250	6.171
Consumption	Fruit-10year	0.2	86	g/d	55.969	679
Occupancy	Indoors-Summer-Adult	0.2	11	hr/w	88.057	127
Media	Pb-210 in Water	0.2	59	Bq/L	0.023	0.476
Occupancy	Outdoors-Summer-10year	0.2	18	hr/w	14.554	25.803
Occupancy	Outdoors-Winter-15year	0.1	11	hr/w	8.388	12.056
Consumption	Air-01year	0.1	28	m3/d	5.705	14.385
Occupancy	Outdoors-Winter-05year	0.1	8	hr/w	9.449	12.128
Consumption	Water-05year	0.1	49	L/d	0.333	1.539
Consumption	Air-10year	0.1	23	m3/d	9.854	20.263
Media	Ra-226 in Water	0.1	58	Bq/L	0.0049	0.095
Consumption	SoilDust-05year	0.1	152	g/d	0.0072	0.256
Consumption	RootVeg-10year	0.1	90	g/d	33.368	424
Consumption	Water-Adult	0.1	54	L/d	0.585	2.979
Media	Th-230 in Water	0.1	59	Bq/L	0.00044	0.0095
Consumption	Water-15year	0.1	61	L/d	0.352	2.238
Occupancy	Outdoors-Summer-Adult	0.1	12	hr/w	12.493	18.048
Consumption	SoilDust-Adult	0.1	38	g/d	0.024	0.096
Consumption	Air-Adult	0.1	25	m3/d	10.283	23.320
Occupancy	Indoors-Summer-05year	0.1	8	hr/w	99.552	127
Consumption	SoilDust-15year	0.1	40	g/d	0.024	0.096
Media	Radon Outdoors	0.0	89	Bq/m3	3.042	35.051
Consumption	Water-01year	0.0	65	L/d	0.188	1.329
Consumption	Fruit-Adult	0.0	81	g/d	57.514	643
Consumption	OtherVeg-15year	0.0	111	g/d	18.583	372
Consumption	RootVeg-15year	0.0	79	g/d	60.447	580
Consumption	Water-10year	0.0	49	L/d	0.327	1.518
Occupancy	Outdoors-Winter-10year	0.0	8	hr/w	9.476	12.142
Occupancy	Indoors-Summer-15year	0.0	10	hr/w	87.366	119
Occupancy	Indoors-Winter-10year	0.0	8	hr/w	105	133
Occupancy	Outdoors-Winter-Adult	0.0	11	hr/w	8.350	12.036

Table B.3.36(b) - Cont'd
Summary of Variability of Lifetime Risk
from All Radiological Sources for All Age Groups in Zone 4

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pc Sample Valu
Consumption	RootVeg-01year	0.0	85	g/d	24.067	2
Consumption	OtherVeg-Adult	0.0	96	g/d	27.887	3
Occupancy	Indoors-Winter-05year	0.0	8	hr/w	105	1
Occupancy	Indoors-Winter-Adult	0.0	12	hr/w	92.276	1
Consumption	Fruit-15year	0.0	93	g/d	49.023	6
Occupancy	Indoors-Summer-10year	0.0	8	hr/w	99.571	1
Consumption	OtherVeg-05year	0.0	115	g/d	15.033	2
Consumption	RootVeg-05year	0.0	86	g/d	33.149	4
Consumption	Air-05year	0.0	22	m3/d	9.915	20.0
Consumption	SoilDust-10year	0.0	155	g/d	0.0067	0.2
Consumption	OtherVeg-01year	0.0	104	g/d	9.739	1
Consumption	OtherVeg-10year	0.0	120	g/d	16.082	2
Occupancy	Outdoors-Summer-15year	0.0	21	hr/w	12.816	25.7
Media	Gamma Outdoors	0.0	11	uR/h	7.380	10.7
Occupancy	Indoors-Winter-15year	0.0	12	hr/w	92.102	1
Consumption	Fruit-05year	0.0	90	g/d	56.995	6
Consumption	RootVeg-Adult	0.0	81	g/d	47.751	4
Media	Pb-210 in Air	0.0	93	Bq/m3	0.00015	0.00
Consumption	Air-15year	0.0	26	m3/d	10.124	23.0
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.1
Media	U-238 in SoilDust	0.0	75	Bq/g	0.0019	0.0
Media	Ra-226 in SoilDust	0.0	43	Bq/g	0.0074	0.0
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.6
Consumption	Fruit-01year	0.0	78	g/d	58.487	5
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.0
Consumption	SoilDust-01year	0.0	150	g/d	0.0070	0.2
Media	Po-210 in Air	0.0	58	Bq/m3	2.42E-6	0.000
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.0
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.00
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.0
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.6
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.00
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.000
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.3

Table B.3.37(a)
Summary of Contributions to Lifetime Risk
from Radon for All Age Groups in Deloro

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Radon	0.0047	100.0	0.0033	0.013	95
Total	0.0047	100.0	0.0033	0.013	95

Table B.3.37(b)
Summary of Variability of Lifetime Risk
from Radon for All Age Groups in Deloro

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pct Sampled Value
Media	Radon Indoors	98.5	96	Bq/m3	9.617	167
Occupancy	Indoors-Summer-15year	0.3	10	hr/w	87.366	119
Occupancy	Indoors-Winter-Adult	0.2	12	hr/w	92.276	132
Occupancy	Indoors-Summer-Adult	0.2	11	hr/w	88.057	127
Occupancy	Outdoors-Winter-05year	0.1	8	hr/w	9.449	12.128
Occupancy	Outdoors-Winter-Adult	0.1	11	hr/w	8.350	12.036
Occupancy	Indoors-Winter-15year	0.1	12	hr/w	92.102	133
Occupancy	Outdoors-Summer-Adult	0.1	12	hr/w	12.493	18.048
Media	Radon Outdoors	0.0	75	Bq/m3	1.677	15.694
Occupancy	Indoors-Winter-10year	0.0	8	hr/w	105	133
Occupancy	Outdoors-Summer-15year	0.0	21	hr/w	12.816	25.731
Occupancy	Outdoors-Summer-10year	0.0	18	hr/w	14.554	25.803
Occupancy	Outdoors-Winter-10year	0.0	8	hr/w	9.476	12.142
Occupancy	Indoors-Summer-05year	0.0	8	hr/w	99.552	127
Occupancy	Indoors-Winter-05year	0.0	8	hr/w	105	133
Occupancy	Indoors-Summer-10year	0.0	8	hr/w	99.571	127
Occupancy	Outdoors-Summer-05year	0.0	17	hr/w	14.716	25.582
Occupancy	Outdoors-Winter-15year	0.0	11	hr/w	8.388	12.056
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.380

Table B.3.38(a)
Summary of Contributions to Lifetime Risk
from Radon for All Age Groups in Background

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Radon	0.0044	100.0	0.0026	0.015	132
Total	0.0044	100.0	0.0026	0.015	132

Table B.3.38(b)
Summary of Variability of Lifetime Risk
from Radon for All Age Groups in Background

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pc Sample Valu
Media	Radon Indoors	99.1	138	Bq/m3	4.785	18
Occupancy	Indoors-Summer-Adult	0.2	11	hr/w	88.057	12
Occupancy	Indoors-Winter-05year	0.1	8	hr/w	105	13
Occupancy	Outdoors-Summer-10year	0.1	18	hr/w	14.554	25.80
Occupancy	Outdoors-Winter-Adult	0.1	11	hr/w	8.350	12.03
Occupancy	Indoors-Summer-05year	0.1	8	hr/w	99.552	12
Occupancy	Indoors-Summer-15year	0.1	10	hr/w	87.366	11
Occupancy	Outdoors-Winter-10year	0.0	8	hr/w	9.476	12.14
Occupancy	Outdoors-Winter-05year	0.0	8	hr/w	9.449	12.12
Occupancy	Outdoors-Summer-15year	0.0	21	hr/w	12.816	25.73
Occupancy	Indoors-Winter-15year	0.0	12	hr/w	92.102	13
Media	Radon Outdoors	0.0	26	Bq/m3	6.531	15.45
Occupancy	Indoors-Winter-10year	0.0	8	hr/w	105	13
Occupancy	Outdoors-Winter-15year	0.0	11	hr/w	8.388	12.05
Occupancy	Outdoors-Summer-Adult	0.0	12	hr/w	12.493	18.04
Occupancy	Outdoors-Summer-05year	0.0	17	hr/w	14.716	25.58
Occupancy	Indoors-Winter-Adult	0.0	12	hr/w	92.276	13
Occupancy	Indoors-Summer-10year	0.0	8	hr/w	99.571	12
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.38

Table B.3.39(a)
Summary of Contributions to Lifetime Risk
from Gamma for All Age Groups in Deloro

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.0011	100.0	0.0011	0.0015	17
Total	0.0011	100.0	0.0011	0.0015	17

Table B.3.39(b)
Summary of Variability of Lifetime Risk
from Gamma for All Age Groups in Deloro

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pct Sample Value
Media	Gamma Indoors	90.8	19	uR/h	3.649	6.63
Occupancy	Indoors-Summer-Adult	4.9	11	hr/w	88.057	12
Media	Gamma Outdoors	1.4	13	uR/h	5.430	8.28
Occupancy	Indoors-Winter-Adult	0.8	12	hr/w	92.276	13
Occupancy	Indoors-Summer-05year	0.5	8	hr/w	99.552	12
Occupancy	Outdoors-Summer-Adult	0.4	12	hr/w	12.493	18.04
Occupancy	Indoors-Summer-15year	0.3	10	hr/w	87.366	11
Occupancy	Indoors-Winter-05year	0.1	8	hr/w	105	13
Occupancy	Outdoors-Summer-15year	0.1	21	hr/w	12.816	25.73
Occupancy	Outdoors-Winter-10year	0.1	8	hr/w	9.476	12.14
Occupancy	Outdoors-Winter-Adult	0.1	11	hr/w	8.350	12.03
Occupancy	Indoors-Winter-10year	0.0	8	hr/w	105	13
Occupancy	Indoors-Winter-15year	0.0	12	hr/w	92.102	13
Occupancy	Outdoors-Summer-05year	0.0	17	hr/w	14.716	25.58
Occupancy	Outdoors-Winter-05year	0.0	8	hr/w	9.449	12.12
Occupancy	Indoors-Summer-10year	0.0	8	hr/w	99.571	12
Occupancy	Outdoors-Winter-15year	0.0	11	hr/w	8.388	12.05
Occupancy	Outdoors-Summer-10year	0.0	18	hr/w	14.554	25.80
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.38

Table B.3.40(a)
Summary of Contributions to Lifetime Risk
from Gamma for All Age Groups in Background

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Gamma	0.00095	100.0	0.00095	0.0012	15
Total	0.00095	100.0	0.00095	0.0012	15

Table B.3.40(b)
Summary of Variability of Lifetime Risk
from Gamma for All Age Groups in Background

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pc Sample Valu
Media	Gamma Indoors	83.0	16	uR/h	3.120	5.18
Media	Gamma Outdoors	7.4	26	uR/h	3.244	7.77
Occupancy	Indoors-Summer-Adult	5.0	11	hr/w	88.057	12
Occupancy	Indoors-Summer-05year	1.6	8	hr/w	99.552	12
Occupancy	Indoors-Winter-Adult	1.3	12	hr/w	92.276	13
Occupancy	Indoors-Summer-15year	0.6	10	hr/w	87.366	11
Occupancy	Outdoors-Summer-05year	0.2	17	hr/w	14.716	25.58
Occupancy	Indoors-Winter-05year	0.2	8	hr/w	105	13
Occupancy	Outdoors-Summer-Adult	0.2	12	hr/w	12.493	18.04
Occupancy	Outdoors-Summer-15year	0.1	21	hr/w	12.816	25.73
Occupancy	Indoors-Summer-10year	0.1	8	hr/w	99.571	12
Occupancy	Outdoors-Winter-05year	0.1	8	hr/w	9.449	12.12
Occupancy	Indoors-Winter-10year	0.0	8	hr/w	105	13
Occupancy	Outdoors-Winter-Adult	0.0	11	hr/w	8.350	12.03
Occupancy	Outdoors-Winter-15year	0.0	11	hr/w	8.388	12.05
Occupancy	Outdoors-Winter-10year	0.0	8	hr/w	9.476	12.14
Occupancy	Outdoors-Summer-10year	0.0	18	hr/w	14.554	25.80
Occupancy	Indoors-Winter-15year	0.0	12	hr/w	92.102	13
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.38

Table B.3.41(a)
Summary of Contributions to Lifetime Risk
from Other Sources for All Age Groups in Deloro

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Water	0.00074	91.4	0.00067	0.0016	63
Other	0.00007	8.6	0.00006	0.00015	63
Total	0.0008	100.0	0.00073	0.0017	57

Table B.3.41(b)
Summary of Variability of Lifetime Risk
from Other Sources for All Age Groups in Deloro

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pct Sampled Value
Media	Pb-210 in Water	67.6	59	Bq/L	0.022	0.475
Consumption	Water-Adult	19.7	54	L/d	0.585	2.979
Consumption	Water-05year	1.9	49	L/d	0.333	1.539
Consumption	Water-15year	1.0	61	L/d	0.352	2.238
Media	Pb-210 in Air	0.8	74	Bq/m3	0.00016	0.0014
Media	Ra-226 in Water	0.5	57	Bq/L	0.0056	0.096
Consumption	OtherVeg-15year	0.4	111	g/d	18.583	372
Consumption	Water-10year	0.4	49	L/d	0.327	1.518
Consumption	OtherVeg-10year	0.3	120	g/d	16.082	293
Consumption	Water-01year	0.2	65	L/d	0.188	1.329
Consumption	OtherVeg-Adult	0.1	96	g/d	27.887	366
Occupancy	Outdoors-Summer-15year	0.1	21	hr/w	12.816	25.731
Consumption	Fruit-15year	0.1	93	g/d	49.023	664
Consumption	SoilDust-05year	0.1	152	g/d	0.0072	0.256
Occupancy	Indoors-Summer-15year	0.1	10	hr/w	87.366	119
Occupancy	Indoors-Winter-15year	0.1	12	hr/w	92.102	133
Consumption	Fruit-01year	0.1	78	g/d	58.487	587
Consumption	Fruit-Adult	0.0	81	g/d	57.514	643
Consumption	Air-05year	0.0	22	m3/d	9.915	20.027
Media	Po-210 in Water	0.0	58	Bq/L	0.00049	0.0095
Consumption	Air-01year	0.0	28	m3/d	5.705	14.385
Consumption	SoilDust-Adult	0.0	38	g/d	0.024	0.096
Occupancy	Outdoors-Summer-10year	0.0	18	hr/w	14.554	25.803
Occupancy	Outdoors-Winter-10year	0.0	8	hr/w	9.476	12.142
Consumption	SoilDust-10year	0.0	155	g/d	0.0067	0.256
Occupancy	Indoors-Summer-Adult	0.0	11	hr/w	88.057	127
Consumption	RootVeg-10year	0.0	90	g/d	33.368	424
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Consumption	Air-10year	0.0	23	m3/d	9.854	20.263
Consumption	RootVeg-01year	0.0	85	g/d	24.067	259
Occupancy	Outdoors-Winter-05year	0.0	8	hr/w	9.449	12.128
Transfer	Air (outdoor-indoor)	0.0	25	--	0.292	0.698
Consumption	RootVeg-05year	0.0	86	g/d	33.149	426
Consumption	Air-Adult	0.0	25	m3/d	10.283	23.320

Table B.3.41(b) - Cont'd
Summary of Variability of Lifetime Risk
from Other Sources for All Age Groups in Deloro

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pc Sample Valu
Consumption	OtherVeg-01year	0.0	104	g/d	9.739	19
Occupancy	Outdoors-Winter-Adult	0.0	11	hr/w	8.350	12.03
Occupancy	Indoors-Winter-05year	0.0	8	hr/w	105	13
Occupancy	Outdoors-Summer-Adult	0.0	12	hr/w	12.493	18.04
Consumption	Air-15year	0.0	26	m3/d	10.124	23.00
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008
Media	U-238 in SoilDust	0.0	43	Bq/g	0.0022	0.008
Transfer	Biotransfer for Pb-210	0.0	165	--	0.00021	0.009
Occupancy	Indoors-Winter-10year	0.0	8	hr/w	105	13
Consumption	Fruit-10year	0.0	86	g/d	55.969	67
Consumption	OtherVeg-05year	0.0	115	g/d	15.033	27
Consumption	RootVeg-15year	0.0	79	g/d	60.447	58
Consumption	Fruit-05year	0.0	90	g/d	56.995	67
Occupancy	Indoors-Summer-10year	0.0	8	hr/w	99.571	12
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Consumption	SoilDust-15year	0.0	40	g/d	0.024	0.09
Consumption	RootVeg-Adult	0.0	81	g/d	47.751	45
Occupancy	Indoors-Summer-05year	0.0	8	hr/w	99.552	12
Occupancy	Outdoors-Winter-15year	0.0	11	hr/w	8.388	12.05
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69
Media	U-238 in Water	0.0	40	Bq/L	0.0019	0.01
Occupancy	Indoors-Winter-Adult	0.0	12	hr/w	92.276	13
Media	Ra-226 in SoilDust	0.0	36	Bq/g	0.0092	0.02
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Transfer	Backyard Garden (%)	0.0	59	--	0.0078	0.14
Media	Th-230 in Water	0.0	59	Bq/L	0.00043	0.009
Occupancy	Outdoors-Summer-05year	0.0	17	hr/w	14.716	25.58
Consumption	SoilDust-01year	0.0	150	g/d	0.0070	0.27
Media	Po-210 in Air	0.0	51	Bq/m3	9.76E-6	0.0000
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.38

Table B.3.42(a)
Summary of Contributions to Lifetime Risk
from Other Sources for All Age Groups in Background

Analyte	Mean	% Total	Median	95th Percentile	C.V. (%)
Water	0.00074	88.1	0.00069	0.0015	60
Other	0.0001	11.9	0.00009	0.00017	40
Total	0.00084	100.0	0.0008	0.0016	53

Table B.3.42(b)
Summary of Variability of Lifetime Risk
from Other Sources for All Age Groups in Background

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pct Sampled Value
Media	Pb-210 in Water	71.5	58	Bq/L	0.025	0.474
Consumption	Water-Adult	12.9	54	L/d	0.585	2.979
Consumption	Water-15year	2.1	61	L/d	0.352	2.238
Consumption	Water-05year	2.0	49	L/d	0.333	1.539
Consumption	Water-01year	1.8	65	L/d	0.188	1.329
Media	Ra-226 in Water	0.6	59	Bq/L	0.0053	0.095
Media	Pb-210 in Air	0.3	35	Bq/m3	0.0004	0.0012
Consumption	Water-10year	0.3	49	L/d	0.327	1.518
Consumption	Fruit-01year	0.2	78	g/d	58.487	587
Occupancy	Indoors-Summer-10year	0.2	8	hr/w	99.571	127
Consumption	Air-10year	0.2	23	m3/d	9.854	20.263
Consumption	RootVeg-05year	0.1	86	g/d	33.149	426
Transfer	Air (outdoor-indoor)	0.1	25	--	0.292	0.698
Consumption	OtherVeg-01year	0.1	104	g/d	9.739	192
Consumption	SoilDust-01year	0.1	150	g/d	0.0070	0.270
Media	Po-210 in Water	0.1	58	Bq/L	0.00049	0.0095
Consumption	OtherVeg-05year	0.1	115	g/d	15.033	273
Transfer	Backyard Garden (%)	0.1	59	--	0.0078	0.141
Occupancy	Indoors-Winter-Adult	0.1	12	hr/w	92.276	132
Occupancy	Outdoors-Summer-15year	0.1	21	hr/w	12.816	25.733
Media	U-238 in SoilDust	0.1	136	Bq/g	0	0.935
Transfer	Biotransfer for Pb-210	0.1	165	--	0.00021	0.0092
Occupancy	Outdoors-Winter-10year	0.1	8	hr/w	9.476	12.142
Occupancy	Indoors-Winter-15year	0.1	12	hr/w	92.102	131
Consumption	RootVeg-01year	0.1	85	g/d	24.067	259
Consumption	SoilDust-15year	0.1	40	g/d	0.024	0.096
Consumption	Fruit-10year	0.1	86	g/d	55.969	679
Transfer	Biotransfer for Ra-226	0.0	163	--	0.00028	0.011
Consumption	RootVeg-15year	0.0	79	g/d	60.447	580
Consumption	OtherVeg-10year	0.0	120	g/d	16.082	291
Occupancy	Outdoors-Summer-Adult	0.0	12	hr/w	12.493	18.048
Consumption	Air-15year	0.0	26	m3/d	10.124	23.000
Consumption	Air-05year	0.0	22	m3/d	9.915	20.027
Consumption	Air-Adult	0.0	25	m3/d	10.283	23.320

Table B.3.42(b) - Cont'd
Summary of Variability of Lifetime Risk
from Other Sources for All Age Groups in Background

Factor Type	Factor Description	Variability Explained (%)	C.V. in Factor (%)	Units	5th Pctl Sampled Value	95th Pc Sample Valu
Media	Ra-226 in SoilDust	0.0	29	Bq/g	0.013	0.03
Consumption	SoilDust-Adult	0.0	38	g/d	0.024	0.09
Consumption	Fruit-15year	0.0	93	g/d	49.023	66
Occupancy	Indoors-Summer-Adult	0.0	11	hr/w	88.057	12
Occupancy	Indoors-Winter-05year	0.0	8	hr/w	105	13
Occupancy	Indoors-Winter-10year	0.0	8	hr/w	105	13
Consumption	SoilDust-05year	0.0	152	g/d	0.0072	0.25
Media	Po-210 in Air	0.0	34	Bq/m3	0.00004	0.0001
Occupancy	Indoors-Summer-05year	0.0	8	hr/w	99.552	12
Consumption	Air-01year	0.0	28	m3/d	5.705	14.38
Consumption	RootVeg-10year	0.0	90	g/d	33.368	42
Transfer	Soil (outdoor-indoor)	0.0	24	--	0.305	0.69
Transfer	Biotransfer for U-238	0.0	151	--	0.00009	0.003
Occupancy	Indoors-Summer-15year	0.0	10	hr/w	87.366	11
Consumption	RootVeg-Adult	0.0	81	g/d	47.751	45
Consumption	OtherVeg-Adult	0.0	96	g/d	27.887	36
Consumption	SoilDust-10year	0.0	155	g/d	0.0067	0.25
Occupancy	Outdoors-Winter-05year	0.0	8	hr/w	9.449	12.12
Occupancy	Outdoors-Summer-05year	0.0	17	hr/w	14.716	25.58
Transfer	Biotransfer for Th-230	0.0	147	--	0.0003	0.01
Consumption	Fruit-Adult	0.0	81	g/d	57.514	64
Media	Th-230 in Water	0.0	57	Bq/L	0.00059	0.009
Occupancy	Outdoors-Winter-15year	0.0	11	hr/w	8.388	12.05
Consumption	Fruit-05year	0.0	90	g/d	56.995	67
Occupancy	Outdoors-Summer-10year	0.0	18	hr/w	14.554	25.80
Occupancy	Outdoors-Winter-Adult	0.0	11	hr/w	8.350	12.03
Transfer	Biotransfer for Po-210	0.0	178	--	0.00002	0.0008
Consumption	OtherVeg-15year	0.0	111	g/d	18.583	37
Media	U-238 in Water	0.0	40	Bq/L	0.0020	0.01
Occupancy	Outdoors-Summer-01year	0.0	0	hr/w	18.380	18.38

APPENDIX C

METHODOLOGY USED TO CALCULATE DOSE AND RISK

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APPENDIX C: METHODOLOGY USED TO CALCULATE DOSE AND RISK

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APPENDIX C: METHODOLOGY USED TO CALCULATE DOSE AND RISK

This appendix describes the equations used to calculate dose and risk in this assessment. Further details on specific parameter values are described in the main body of the report. Risks were calculated for several pathways and receptor scenarios. The variables used in the receptor scenarios included location (zone) within Deloro (as well as background exposures) and the age of the receptor.

C.1 OVERALL APPROACH

The overall approach was:

- determine media concentrations and exposure rates based on measured data;
- calculate intakes of radioactivity and exposures from media concentrations and exposure rates;
- estimate annual dose from radioactivity intake and exposures; and
- determine risk from the dose.

Media concentrations were available directly from measurements for many pathways; however, some conversions in the units were required and concentrations for some pathways had to be estimated from concentrations measured in other media.

The intake (or exposure) rate via a pathway was:

$$i = m * t$$

where:

i	is the intake (or exposure) rate and was usually expressed on a daily basis
m	is the media concentration or exposure rate applicable to the pathway
t	is the duration of exposure or the quantity and usually expressed on a daily basis

For some pathways, intakes were calculated separately for indoor and outdoor exposures since the media concentrations and duration (extent) of exposure differed between indoor and outdoor environments. These pathways included: radon, gamma radiation, air (particulate) inhalation and soil/dust ingestion.

Annual doses were determined for each pathway by multiplying the intake (or exposure) by dose conversion factors. Annual doses for a particular receptor scenario were determined by summing the doses from individual pathways. Risks from one year of exposure were calculated by multiplying the annual dose rate by the risk factor applicable to that age.

Lifetime risks for a particular location (zone) were determined by first multiplying the annual risks predicted for each age group by the number of years in each age group, and then summing the risks over all the age groups. The number of years for each age group is given in Table C.1.

Table C.1

Number of Years in Each Age Group

Age Group	Number of Years In Age Group
1 year old	2
5 year old	5
10 year old	5
15 year old	5
Adult	53
Lifetime (Total)	70

The following sections show specific applications of the general approach to calculated risk levels. Table C.2 summarizes the purpose of the calculations.

Table C.2

Outline of Dose and Risk Calculations

	Media Concentrations and Exposure Rates			Intakes/Exposures	
	Empirical Measurements	Media Values used in the Risk Assessment	Units	Intake/Exposure Rates	Units
Indoor Radon	Above RL	conversion to different units	WL	calculated from hours spent indoor	WLM
Outdoor Radon	One Above RL	conversion to different units	WL	calculated from hours spent outdoors	WLM
Indoor Gamma	Above RL	no changes	µR/h	calculated from hours spent indoors	R/y
Outdoor Gamma	Above RL	no changes	µR/h	calculated from hours spent outdoor	R/y
Soil	Above RL for U and Ra-226	below RL radionuclides set to Ra-226 activity concentrations	Bq/g	prorated to proportion of time spent outdoors	Bq/y
(Settled Indoor) Dust	Most Below RL	predicted from soil concentrations	Bq/g	prorated to proportion of time spent indoors	Bq/y
Indoor Air	Most Below RL	predicted from outdoor air concentrations	Bq/m^3	from inhalation rate and time spent indoors	Bq/y
Outdoor Air	Above RL for Po-210 and Pb-210	based on soil concentrations for radionuclides <RL	Bq/m^3	from inhalation rate and time spent outdoors	Bq/y
Vegetation	Not measured	calculated from soil concentrations	Bq/g	based on consumption rate and proportion of diet from backyard garden	Bq/y
Drinking Water	Most Below RL	based on the RL	Bq/L	L/y from consumption rate	Bq/y

RL = reporting limit.

C.2 MEDIA CONCENTRATIONS AND EXPOSURE RATES

Media concentrations were derived to the extent possible from direct measurements of media in Deloro and baseline/background measurements from the literature. In many cases, the measured concentrations were below reporting limits and concentrations were based on concentrations measured in related media. Concentrations and exposure rates varied depending on the location (zone) within Deloro for all pathways except drinking water. Concentrations and exposure rates also depended on being indoor or outdoors. The algorithms were set-up to provide the capability for seasonal differences in concentrations; however, as explained in Appendix D (Section D.1), seasonal variations were not included in this assessment.

The following sections describe media-specific methods for using measured values to define media concentrations or exposure rates.

Radon

Measured radon concentrations were converted to radon progeny concentrations with the following equation:

$$m = (c/37) * f)/100$$

where:

- m is the radon decay progeny (RDP) concentration (WL)
- f is the RDP equilibrium factor (a value of 0.4 was used for indoor measurements and a value of 0.7 for outdoor measurements)
- c is the measured radon concentration (outdoors and indoors) (Bq/m^3)
- 37 the factor used to convert from Bq/m^3 to pCi/L
- 100 the factor used in the conversion of radon concentration in pCi/L to RDP concentration in WL

Gamma Radiation

Measured gamma radiation levels for indoor and outdoor conditions were reported as exposure rates in air with units of μR/h. No further calculations were required and the following equation applied:

$$m = c.$$

where:

- m is the exposure rate for gamma radiation (μR/h); exposure rates were considered independent of season
- c is the gamma exposure rates (μR/h) measured in the outdoor or indoor locations

Soil/Dust Concentrations

Soil concentrations of uranium and Ra-226 were measured on each property in the Village of Deloro. The measured concentrations were used directly in the risk assessment. The soil concentrations of other radionuclides in the U-238 series (Th-230, Pb-210, Po-210) were set equal to the measured Ra-226 concentration for the risk assessment

Indoor (settled) dust concentrations were below the reporting limit for most radionuclides. Indoor (settled) dust concentrations were predicted from outdoor soil concentrations using an indoor-to-outdoor scaling factor.

$$m_{indoor} = m_{outdoor} * f$$

where:

m_{indoor} is the indoor (settled) dust concentration (Bq/g)
$m_{outdoor}$ is the outdoor soil concentration (Bq/g)
f is a factor (mean of 0.5) relating indoor (settled) dust to outdoor soil concentrations

Air Concentrations

Measurements were conducted indoors and outdoors for the radionuclides under consideration. Most of the measurements were below reporting limit and hence concentrations were estimated from outdoor soil concentrations and factors relating indoor to outdoor concentrations.

Some outdoor measurements for Po-210 and Pb-210 were above the reporting limit and these were used directly in the risk assessment. For these radionuclides:

$$m_{outdoor} = c_{outdoor}$$

where:

$m_{outdoor}$ is the outdoor air concentration (Bq/m^3)
$c_{outdoor}$ is the measured outdoor air concentration (Bq/m^3)

Outdoor concentrations for the other radionuclides were calculated from the soil concentrations

$$m_{outdoor} = c_{soil} * \left(50 \times 10^{-6}\right)$$

where:

$m_{outdoor}$ is the outdoor air concentration (Bq/m^3)
c_{soil} is the soil concentration (Bg/g)
$50x10^{-6}$ is the assumed outdoor suspended particulate concentration (g/m^3)

Measured indoor concentrations were below the reporting limits; therefore, indoor air (particulate) concentrations were predicted from outdoor measurements using:

$$m_{indoor} = m_{outdoor} * f$$

where:

m_{indoor} is the indoor air concentration (Bq/m^3)
$m_{outdoor}$ is the outdoor air concentration (Bq/m^3)
f is a factor (mean of 0.5) relating indoor concentration to outdoor concentration

Concentrations in Garden Produce

Concentrations in garden produce were calculated from soil concentrations using radionuclide-specific soil-to-plant transfer factors:

$$m_{vegetation} = c_{soil} * f_{bio}$$

where:

$m_{vegetation}$ is the concentration (wet basis) in the vegetation (Bq/g)
c_{soil} is the soil concentration (dry basis) (Bq/g)
f_{bio} is the soil-to-plant transfer factor (this varied by radionuclide)

Drinking Water Concentrations

Measured water concentrations were for the most part below reporting limits. There was no reasonable basis to estimate these concentrations from other measured media; therefore, the reporting limits were used to define a distribution of concentrations (see main text).

C.3 Intake and Exposure Rates

Radionuclide intake rates and exposure rates (gamma radiation or radon decay progeny) depend on the age of the receptor because of the age-dependency of the duration of exposure to external gamma radiation and radon decay progeny (RDP), the amount inhaled or the amount ingested. Although not related to geographical location, the intake and consumption rates for many pathways are related to the time spent indoors and outdoors. Intakes of radioactivity were based on multiplying the media concentrations by the duration or amount of the media consumed.

Radon

The RDP exposure rate was determined from the duration and RDP concentration using:

$$i = (m * t / 170) * d$$

where:

i	is the exposure rate (WLM/y)
m	is the RDP concentration (WL)
t	is the duration (h/d)
170	is a conversion factor between WL and WLM
d	is the days per year (120 for winter season, 245 for other)

Gamma Radiation

Annual exposure rates for gamma radiation were calculated from the hourly exposure rate and the exposure duration using:

$$i = (m * t * 1 \times 10^{-6}) * d$$

where:

i	is the exposure rate for gamma radiation (R/y)
m	is the gamma radiation exposure level (μR/h)
t	is the duration at the location (h/d)
$1x10^{-6}$	is a conversion factor from μR to R
d	is the number of days per year (120 for winter season, 245 for other)

Soil and Dust

Intake for the soil and dust pathway was given by:

$$i = (m * (t / 24) * r) * d$$

where:

i	is the intake for the radionuclide (Bq/y)
m	is the concentration of the radionuclide (Bq/g)
r	is the ingestion rate (g/d)
t	is the exposure time (h/d)
24	is the conversion from hours to days
d	is the number of days per year (120 for winter, 245 for other)

Inhalation

Intake for the inhalation pathway was based on the amount of air inhaled.

$$i = (m * (t / 24) * r) * d$$

where:

- i is the intake for the radionuclide (Bq/y)
- m is the concentration of the radionuclide (Bq/m^3)
- r is the inhalation rate (m^3/d)
- t is the exposure time (h/d)
- d is the number of days per year (120 for winter, 245 for other)

Garden Produce

The intake of radionuclides via the garden produce pathway was determined by multiplying the produce concentration by the consumption rate of garden produce:

$$i = (m * c * p_{backyard}) * d$$

where:

- i is the intake for the radionuclide (Bq/y)
- m is the concentration (wet weight) in the produce (Bq/g)
- c is the consumption rate (wet basis) of garden produces (g/d)
- $p_{backyard}$ is the proportion of the produce from local home gardens
- d is the number of days per year (365 days)

Water Consumption

The intake of radionuclides via the drinking water pathway was determined by multiplying the water concentration by the consumption rate of water:

$$i = (m * c) * d$$

where:

- i is the intake for the radionuclide (Bq/y)
- m is the concentration in the water (Bq/L)
- c is the consumption rate (L/d)
- d is the number of days per year (365 days)

C.4 DETERMINISTIC ASSESSMENT

Risks were calculated deterministically with two separate calculations, first using the deterministic means of the impact parameters and then the plausible maximum values.

The deterministic mean calculation was conducted using the mean value for all parameters concerning media concentrations, exposure rates, consumption rates and exposure durations. Biological transfer factors and indoor/outdoor factors were also assigned the mean value.

The calculation for plausible maximum risk used the maximum plausible values for media concentrations, exposure rates, consumption rates and exposure durations.

C.5 PROBABILISTIC ASSESSMENT

The objective of the probabilistic assessment was to estimate the range of lifetime risks for Deloro residents by probabilistically sampling from the media concentrations or exposure rates and from the consumption or exposure time patterns. The annual dose rate was simulated for each location (zone), and age group and these dose rates were used to calculate lifetime risks for each location (zone).

Each probabilistic trial produced an estimate of lifetime risk for a person living for 70 years in Deloro and beginning at birth. The probabilistic analyses were conducted separately for each of the four zones in Deloro and for the background conditions. Estimates for overall Deloro conditions were based on sampling from the overall distribution of media concentrations or exposure rates rather than combining the risk estimates from each zone. The procedure was as follows:

1) Media concentrations and exposure rates were probabilistically sampled (simple random Monte Carlo) from the distributions for the zone or area (shown in Table 2.1 of the report). Concentrations for other media were developed by sampling from the distributions of transfer factors and indoor/outdoor ratios. Media concentrations and exposure rates were kept constant throughout the receptor's lifetime to reflect the scenario where the receptors remain at the same residence while living in Deloro.

2) The consumption rates and exposure durations were probabilistically sampled for each of the five age groups. It was assumed that the sampled consumption or exposure durations did not change for the period of time while the receptor was in that age group, i.e. these distributions were sampled only once per trial for each age group.

3) Annual intakes for each pathway and age group were estimated by multiplying the sampled media concentration by the sampled consumption rate/exposure duration.

4) Dose rates for each age group and pathway were determined by multiplying the probabilistic intake rate by the age-dependent dose conversion factors. The doses were summed across the various pathways to get dose rates by age group and location. The distribution of these values was reported.

5) The risk from the annual dose rate was determined using age-specific risk factors. The lifetime risk value for each trial was determined by summing the risks for each year.

6) Steps 1 through 5 were reported to develop the distribution of annual dose rates and lifetime risk.

APPENDIX D

RESPONSE TO COMMENTS ON PRELIMINARY DRAFT REPORT

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APPENDIX D: RESPONSE TO COMMENTS ON PRELIMINARY DRAFT REPORT

D.1 INTRODUCTION

This appendix provides responses to comments from expert external reviewers on the preliminary draft of this radiological risk assessment report (February 1999). Some associated responses to comments on the draft SENES gamma radiation and radon survey report (December 1998, now finalized as SENES 1999) are also included, although the majority of such responses are provided in SENES (1999). The latter include responses to comments from Mr. Arthur Scott of the Radiation Protection Service, Ontario Ministry of Labour, and Mr. Jim Mahoney, MOE Eastern Region. A number of comments by the reviewers relate to the draft summary report prepared by CH2M Gore & Storrie Limited (CG&S). Responses to these comments are being considered separately by CG&S.

D.2 RESPONSE TO COMMENTS FROM DR. HENRY CAPLAN, UNIVERSITY OF SASKATCHEWAN

The following responses refer to the comments entitled "Comments on Deloro Reports – Henry S. Caplan – 6th June 1999." The responses are organized according to the headings given in Dr. Caplan's comments

Indoor Radon

"These measurements seem to have been well done and were carried out in a systematic manner. I presume that the E-PERM detector used was the SST with 210ml capacity though this is not explicitly stated"

> Yes. Indoor radon monitoring was conducted with S-Chamber E-PERMs fitted with ST electrets. The capacity of the S chamber is 200 ml.

"Since Indoor Radon is the dominant contribution to dose, I sought to follow the calculations through for this case starting from the summary Table C.1 [of the data report]. I could not reproduce the overall average 56.6 (I got 75) in Table 2.2 of the [SENES] main report and got a bit higher "maximum". Similarly, the geometric mean for the overall case given as 39.3 in Table 2.1 came out to be 52. I am sure we are looking at different sets of data, but I would be happier if the discrepancy were reconciled."

> The risk assessment used the data for the first floor of the houses as the first floor is the main living area of almost all the residences in Deloro. This is more specifically described in the revised report.

"Turning now to the indoor radon "background"; on page 2-9 of [the SENES] main report three sets of data are mentioned: Cobourg, Sudbury and U.S. Sudbury is touted as the one which "may provide a better comparison to levels in Deloro". However Table 2.2 suggests that it is the U.S.

data which have been used and presumably the distribution in Table 2.1 with its low geometric mean comes from that set too."

Both the Cobourg and Sudbury data were based on instantaneous (grab) measurements. Cobourg is on Lake Ontario (which would tend to lower concentrations relative to an inland site) and the Health Canada Sudbury data were taken under maximized conditions i.e. generally closed windows and doors, and often in basements. Consequently, the Sudbury results should not have been indicated as possibly " ...providing a better comparison to levels in Deloro." In order not to bias the "background" calculations high, the data from single family homes in the large U.S. study were used (which gives an average between the Cobourg and Sudbury results). This is described in the revised text.

Outdoor Radon

"I found these measurements unsatisfactory except that they show that the levels are low. Table 2.3 with its negative results is very ugly. Perhaps "track etch" detectors should have been used since they have the added advantage of insensitivity to gamma rays. Alternatively the E-PERM HST 960 ml might do the job with a longer exposure."

Even #11 for the [name deleted] property [nearest the former mine site] is suspect despite being significantly positive. For this case, I would like to see the raw values for both pairs since that area has high gamma background and the result may [be] the subtraction of two larger numbers..... The failure to obtain experimental values may not be important, since the distributions assumed in Table 2.1 of the main SENES report [for outdoor radon] seem reasonable."

The negative results for outdoor radon shown in the results report properly reflect the uncertainty and variability in the differences of measured values between the open (responding to both radon and gamma radiation levels) and closed (gamma radiation only) detectors. This is a statistically appropriate method for reporting raw data, even if negative concentrations are a physical impossibility. The risk assessment study assigned a reporting limit of 10 Bq/m^3 to the raw data when doing the dose and risk calculations.

The higher radon result for the property nearest the former mine site was indeed calculated from the difference between two larger numbers because the gamma radiation exposure rate measured at that location was elevated. However, since both of the paired detectors gave comparable results, the reported value is likely valid. The gamma radiation levels at each outdoor radon monitoring location are now also shown in the results report.

With respect to the sampling methodology, the selection of the E-PERM SST system was based upon the long-standing successful monitoring program conducted around the waste management areas in Port Hope. Unfortunately the time restrictions placed on the monitoring program for Deloro only allowed a period of 30 days in which to conduct the entire program, therefore the E-PERM SST system was selected. Our previous experience in measuring background outdoor radon concentrations suggests that the exposure period was too short for the deployment of track-etch monitors (2 to 3 months typical exposure periods for these units).

Gamma Radiation Survey

"This survey was well conceived and carried out. The instrumentation used was excellent. However, I found it disconcerting that the units used were Roentgens rather than Rads (a factor of 1.14) which is most unusual. Indeed there is no mention of the calibration and checking of the instruments. Be that as it may, the group is to be commended for its thoroughness and in the finding of "hot spots.

I was very disappointed in the response to higher levels found in the Southeast section near the gate to the [former mine] site. A collimated detector would have quickly determined the amount of "shine" compared to the local contribution. This would also have helped find any "hot spots" concealed by the shine if it exists."

The selection of the gamma survey instrumentation used for the Deloro survey was based upon previous monitoring program experience in Port Hope and Malvern, Ontario (historical LLRW sites resulting from previous radium and uranium processing activities). The core instrument for much of this previous work was the Eberline PRM-7 scintillometer (or an equivalent instrument), which reports in units of microroentgens/hour (μR/h). Most, if not all, previous surveys in the Deloro area have been conducted by both consultants and government staff using this instrument (or an equivalent). For consistency with this previous work, the same type of instruments (scintillometers) calibrated in terms of μR/h, were used for the 1998 monitoring program. The federal Low Level Radioactive Waste Management Office (LLRWMO) maintains radium-226 calibration standards at its field support lab in Port Hope. Gamma radiation instrument calibrations conducted at the LLRWMO Port Hope lab are based upon units of μR/h. A discussion on instrument calibration is provided in the final results report.

With respect to "hot spot follow-up" using collimated detectors, the purpose of the monitoring program was to collect data on existing radiation exposure conditions within the off-site areas of the Village, i.e. not on the former mine site. The program was not designed to characterize the sources of the radioactivity. For this reason, no follow-up work was done; however, the MOE is planning to characterize the various hot-spot areas to assist in the design of effective remediation works to reduce

potential exposure levels in the southeast portion of the Village.

Direct Mine Site Effects

"First, on page 4-4 [of the SENES] main text, there is a reference to a survey of the Mine Site itself (SCIMUS Inc 1999.) 'Gamma radiation fields averaged 74 and 109 μR/h in the Industrial and Young's Creek areas respectively.' It would be interesting to know how far these are from the off-site area where high gamma levels were detected. Then one could comment on the plausible contribution of the shine. The pet peeve is that nay location named in the report should appear on the maps. I am not even sure exactly where the [name deleted] property is.... ."

As noted above, the major objective of the gamma radiation and radon surveys in Deloro was to provide data on environmental levels for use in the radiological risk assessment. The surveys were not specifically designed to assess the source of the levels e.g. elevated indoor radon levels could be natural or possibly due to either sub-surface contamination or naturally elevated radium levels, or a host of other reasons. Similarly, directionally-shielded gamma radiation survey detectors were not used. The former mine site itself and potential remediation measures is the subject of a separate study report prepared by CG&S which gives details on the various site locations. However for perspective, the Young's Creek area is several hundred meters from the western fence line, while the industrial area is immediately adjacent to the fence line. This is now indicated in the risk report. The sources of the elevated gamma radiation levels in the industrial area likely contribute to the measured off-site gamma radiation levels.

Confidentiality prevents the use of specific site identification. In fact, all references to individual properties and any specific addresses have been removed in the final results report, and a general area description is used in their place (e.g. "vacant lot near access gate to mine site"). Boundaries for the various designated areas are now presented in maps for the total investigation area.

"Thus the vague suggestion (SENES main page 5-1) of a gradient of outdoor radon across the town, is perhaps not warranted."

Agreed. The statement in the risk assessment report has been modified and now refers only to the elevated level adjacent to the former mine site.

Gamma Radiation Survey (revisited)

"On page 16 of the SENES Results report, it is stated that gamma ray spectra were measured. These are not reported anywhere even to say that there were no surprises".

The gamma spectrometry data for uranium, thorium and potassium as determined in the field using an Exploranium GR256 are now reported in the final results report.

"In the trivia department, on page 22 the highest measured gamma level was reported as 467μR/h but in Table D.1 the highest entry is 390μR/h."

The summary statistics for the individual residential lots, presented in Table D.1 of the results report, were based upon data collected using only the LAGS system and do not include data from the hand-held survey instruments or the roving GPS system. The LAGS data provided complete coverage of each property and were exclusively selected for the statistical summary to provide consistency in sampling methodology, instrumentation and sample height. However, for the data summary presented on Page 22 of the draft results report, the complete data set from all instruments were used. This is clarified in the final results report.

"For the measurements indoors, the gamma level was determined in order to subtract it from the E-PERM reading. I presume that these results were used to derive the distributions given in Table 2-1 of the main SENES report.

Yes. Indoor gamma radiation levels were measured using scintillometers (reporting in μR/h) at the time of E-PERM deployment and retrieval. These data were used in the calculation of the indoor radon concentrations, and to represent indoor levels in the risk assessment report.

Radionuclides in Drinking Water

"In light of this, I was very surprised at the high values of doses (16% of total) attributed to this source [drinking water].... Unfortunately, someone has flipped the reporting limits for Pb-210 (0.5 Bq/l) and Po-210 (0.01 Bq/l). This makes a profound difference since Po-210 is an alpha emitter. In terms of the conclusions, this may not really matter as explained below."

As stated by Dr. Caplan, the reporting limits for Pb-210 and Po-210 were interchanged in the draft risk report. This has been corrected in Table 2.1 and in the dose and risk calculations. However, this does not make a profound difference to the results since the ingestion dose conversion factors (dose per unit intake) for Pb-210 and Po-210 are generally within a factor of about 2 of each other for all ages (Table 3.6 of the risk report). The revised results show that water contributes to about 11% of the dose and lifetime risk (Tables 4.1, 4.2 of the risk report). As explained in the text, the water dose is still overestimated because the measured values were below the reporting limits.

Suggested Inserts into the Reports

"I think that a paragraph should be inserted to explain the difference between "baseline" and background".

A paragraph has been inserted in Chapter 5 of the revised risk report.

"Let us return to the "water problem" mentioned above..... Thus even if the water borne dose were to go down by a factor of 10, the absolute difference between Deloro and background would remain the same, which implies the incremental risk remains the same. Of course, the fractions would be quite different."

As noted above, the estimated doses and contributions (fractions) to dose from drinking water were not profoundly different after correcting the Pb-210 and Po-210 reporting limits. The fractions changed from 16% in the draft risk report to 11% in the revised report. As suggested by Dr. Caplan, the absolute difference between Deloro and background was not affected by this change.

Other Channels

"I have not had time to analyze in detail the other channels e.g. dust in the air but I have confidence in the measurements made on them. No high levels were found and the doses will be low. This is the case where [SENES] uses background values higher than the measured values."

Information on suitable background values for other locations were taken from the referenced sources. It does not seen unusual to us that the air concentrations measured in Deloro (for those above reporting limits) are lower than values measured elsewhere.

"I did notice that the statistical distributions suggested for radionuclides in the air in the CG&S reports were not the ones used by [SENES]"

This comment is unclear. The CG&S reports do not suggest the type of distributions for radionuclides in air. The SENES report used the available data for Pb-210 and Po-210. (Concentrations of other radionuclides generally below reporting limits were estimated as explained in the text of the risk report.) The Po-210 values were corrected by SENES for decay and ingrowth from Pb-210 during the delay between sampling and analysis (in the order of 40 days) because of the 138 day half-life of Po-210. Because of the minor contributions to dose from airborne radionuclides (less than 1%), the assumed air concentrations had no perceptible impact on the dose and risk calculations.

Conversion of Levels to Exposure, Dose and Risk

"How were seasonal variations taken into account? For example in the winter, when the ground is frozen and there is perhaps 30 cm of snow on the ground, local contributions to outside radon are negligible and even the gammas are appreciably attenuated."

It is recognized that seasonal variations are present in media concentrations and exposure rates. Rather than predict the concentrations and exposure rates for other seasons, the concentrations measured in Deloro during the "Fall" period were assumed to apply for the entire year. As noted by Dr. Caplan, this is considered "conservative" in that it likely overestimates doses from external gamma radiation and outdoor radon. The background measurements were typically based on annual average conditions; hence, doses and risk for Deloro are likely slightly overestimated relative to background conditions.

"Section 3.1.6 of [the SENES] main report describes "Activity Patterns". The mean time indoors was 115hrs/week and the mean time outdoors was 14hrs/week. What happened to the other 39 hours?"

As indicated in the report, the activity patterns were based on the survey data obtained from Deloro residents. The activity patterns were intended to be consistent with the patterns used in the chemical risk assessment for exposure while in Deloro. The people spend a portion of their time outside of Deloro (e.g. at work, school, vacation, etc.). Doses and risks for times spent outside of Deloro were not included in the dose and risk estimates for either Deloro or background exposures.

"It is disconcerting to read, "A uniform distribution with bounds between the mean and plausible maximum was used to describe the data." I hope this really means, "A uniform distribution with the upper bound as the plausible maximum and the lower bound chosen to give the specified mean."

The uniform distributions used in this assessment were assumed to range from a lower bound set equal to the mean value reported in the reference, to an upper bound set equal to the plausible maximum. The mean value of such a distribution will therefore be higher than the mean reported in the reference. The dose and risk estimates are therefore slightly conservative.

Aside

"I know it is fashionable to write reports in "plain language" but a major difficulty I have with this report is the lack of algebra."

A more detailed appendix on the calculation methodology has been added to the risk report.

Return to Activity Patterns etc.

"I do not know how they dealt with the anti-correlations of these distributions. For example, the person with the maximum time indoors must have the minimum time outdoors. That person cannot have the maximum exposure in both."

Time spent indoors and outdoors was considered uncorrelated in the analysis except for control by the age group. Since the modelled receptors do not spend all their time in Deloro (e.g. 24 h/d everyday), it is possible for the receptor to have both the maximum time indoors and the maximum time outdoors without exceeding 24 h/d.

"I have not checked the conversion factors for exposure to dose. However, I did notice that footnote b) in Table 3.7 has those dumb Roentgens again but with the conversion factor the wrong way round."

This typographical error has been corrected.

"The text talks of "sampling" the distributions but I do not know exactly what that means without the algebra. Is it some kind of Monte Carlo calculation?

The sampling in the probabilistic calculations was Monte Carlo selection from the input distributions using simple random sampling. This is now noted in the text. In addition, the methods and equations used to combine the sampled distributions are now described in Appendix C.

"However, it is not clear to me how summing over the zones to get "all Deloro" was done. Were the data weighted number of people resident in each zone?"

The "all Deloro" doses and risks were calculated using the overall distributions of the characterization measurements in Deloro i.e. these overall distributions were sampled to obtain the "all Deloro" results. The results from the individual zones were not agglomerated to produce the "all Deloro" estimates.

The Bottom Line

"I do not think that the conclusions will change much in the next iteration on the analysis. While the manner of presenting the results is fine, I do feel that more emphasis should be placed on the idea that the absolute incremental dose, if any, is smaller than 1mSv."

The text in the risk report has been changed to note that the difference in estimated doses for all zones in Deloro (except Zone 4 closest to the former mine site) and "background" is less than 1 mSv/y. However, as now noted in Chapter 5, this difference should not be considered to necessarily provide an accurate estimate of incremental levels since the background distributions only approximate the Deloro baseline levels.

D.3 RESPONSE TO COMMENTS FROM DR. BLISS TRACY, HEALTH CANADA

The following responses refer to comments from Dr. Bliss Tracy of Health Canada entitled "Deloro Village Health Risk Study"(undated).

"The two SENES reports (Environmental Radiation Monitoring and Radiological Health Risk Assessment) show methodologies and results that are quite thorough and quite adequate for the purpose of the risk assessment. The overall conclusion of these reports appears to be well-founded, i.e., the radiation exposure of a Deloro resident falls within the range of general background exposures to Ontario residents."

"The radon readings are scattered and do not appear to be in any way correlated with distance from the mine site. The highest radon values (284 Bq/m^3 main floor and 392 Bq/m^3 basement) are not unusual in a geological formation in which mineralization is found. There is no indication that any radon levels are enhanced as a result of human activities in the area."

Agreed, with the possible exception of the outdoor radon measurement at the location closest to the former mine site.

"There seem to be some confusion in the report as to which guideline should apply to remediation of the radon levels. The 1977 Federal Provincial Task Force criterion of 150 Bq/m^3 was derived specifically to deal with the clean-up of Port Hope properties that had been contaminated by historic wastes form the radium refining industry in that town. The criterion was also applied to radon mitigation in Elliot Lake homes, which had arguably been affected by the uranium mining operations there. Radon levels in Deloro are apparently not related to any mining or uranium operations. The Health Canada criterion of 800 Bq/m^3 would be more appropriate for radon levels due to purely natural sources."

We agree with the comments on the intended applicability of the Task Force and Health Canada guidelines. However, because previous deliberations on indoor radon levels in Deloro had used the 1977 Task Force criterion as a basis for some remediation work in Deloro (e.g. Knight and Makepeace 1980), it was considered appropriate to refer to this criterion, as well as the more recent Health Canada criterion when discussing the radon measurements.

"All the gamma readings can be considered normal (averages of 5 to 7 μR/hr, maxima of 20 μR/hr or less) except for one or two locations very close to the mine site. The Federal Provincial Task Force Criterion of 100 μR/hr for remediation is probably too high by today's standards. Continuous exposure for 10,000 hours per year would lead to an annual dose of about 1 Rem or 10 mSv per year. This is ten times the public dose limit soon to be adopted in AECB regulations. Remediation measures should be undertaken for locations with gamma readings significantly greater than 20 μR/hr."

It is agreed that the 1977 criterion was set when dose limits were higher. However, maximal continual exposure (generally considered to be 75% of the time or 6570 h/y) to an exposure rate of 100 μR/h from natural uranium radionuclides in the ground would lead to an annual dose of about 3.9 mSv/y. Average longer-term annual doses would be much lower. Nevertheless, the MOE has indicated that any areas in the Deloro with exposure rates above 20 μR/h (immediately adjacent to the former mine site and in three very small pockets in the Village of Deloro) will undergo remediation.

"More analyses may be needed on home-grown produce. Metals and radionuclides present in the soil may not be translocated to vegetables grown in the soil."

Additional analyses may be beneficial as a research topic, but the very minor significance of this exposure pathway in Deloro (< 1% of total dose) indicates that further analyses of produce relative to potential exposures and risks to residents of Deloro are not required. The available radiological data on soil concentrations in Deloro indicate that soil concentrations are relatively low compared to typical background levels, and therefore would not produce elevated concentrations in the garden produce.

D.4 RESPONSE TO COMMENTS FROM MR. MARK GARDINER, LLRWMO

The following responses refer to comments form Mr. Mark Gardiner of the Low-Level Radioactive Waste Management Office (LLRWMO) entitled "LLRWMO Review of the 'Preliminary Draft Radiological Health Risk Assessment for the Village of Deloro' (REF2)" (undated).

"Figure 1.1: Identify areas in Figure 1.1; property identifiers are not legible in F1.1 as referenced in the text."

A new figure with more detail that delineates the study zones within Deloro is now included in the report.

"P2-5, S2.2.1: More explanation would be useful to describe the relationship between Th-230 and Ra-226 concentrations. There are two ways to look at it:

1) Th-230 concentration >> Ra-226, as Th-230 was a waste product during Ra-226 processing operations, or

2) Th-230 concentrations should be more in line with U-238 than Ra-226, as it is part of the natural decay series."

Regarding possibility Number 1, the historical materials shipped to Deloro from the Port Hope refinery underwent a variety of possible processing operations, including processing to recover Ra-226. However, historical Ra-226 removal efficiencies never exceeded about 50%. The waste brought to Deloro from such operations (if any) would therefore only have moderately elevated Th-230/Ra-226 ratios (of 2 or less). Averaged over all the radioactive wastes in Deloro, the ratio would likely be lower.

Regarding possibility Number 2, while Th-230 is a decay product of U-238 (actually U-234) in the natural uranium decay series, the normally higher environmental mobility of uranium relative to thorium and radium suggests that Th-230 concentrations would be closer to those of Ra-226. Moreover, since Ra-226 concentrations in the Deloro soil samples generally exceed the U-238 concentrations, it was conservatively assumed in the risk assessment that the Th-230 concentrations were equal to the Ra-226 concentrations, rather than those of U-238.

"P2-10, S2.3.3, para 2: The LLRWMO has analyzed the MOE regional/provincial soil samples as well.....The most appropriate background soil concentrations would include the MOE regional sample data, as analyzed by LLRWMO. Also, mention of soil concentrations determined by in situ gamma spec measurements taken at ambient Rn-222 monitoring locations should also be made."

The MOE regional sample data was used for background soil concentrations, as described in the revised text. The in-situ gamma spec measurements are noted in the final results report.

"P2-111, S2.3.6, para 4: The average of the total (terrestrial plus cosmic) gross gamma radiation measurements taken at each of the ambient Rn-222 monitoring stations is likely more suitable as a site reference outdoor background.

Also, the report should more strongly reflect the difference between terrestrial and cosmic dose rates...."

Terrestrial gamma radiation exposure rates only (i.e. excluding cosmic exposures) for background exposures were considered more appropriate relative to the Deloro data because the predominant instruments used to measure the exposure rates in

Deloro (sodium iodide scintillometers) are relatively insensitive to cosmic radiation. The text has been edited somewhat to describe this issue more fully.

"In some cases the detection limit was used, in others, half of the detection limit was used. The text should describe the difference."

The CG&S summary report used half the reporting limits when estimating mean values and other statistics for the environmental data. In the risk assessment report, for data below reporting limits, the reporting limit was used in assigning distributions (often uniform) to the data. This is described in various locations in the report.

"Some discussion should be included in the text to help answer the question: Which is the greater error, extrapolating to a distant reference data set or using a smaller regional/local one?"

An objective of the radiological risk assessment was a comparison of risks under current conditions in Deloro with the risks in other Ontario locations without radiological contamination. Natural, background radiation levels vary from area to area so a broader-based reference set provides a more complete description of the range of natural radiation levels. A nearby area may have significantly higher or lower radiation levels than Deloro and interpretation between the radiological levels in the two areas would be difficult.

Natural radiation is highly variable from property to property within any area, particularly with respect to indoor radon concentrations. A quantitative assessment of the change in radiological levels attributable to the former Deloro mine site operations would require baseline levels (for each home) collected prior to such operations. These are unavailable.

"The definition of risk, as used in the report, should also be included in the summary."

The definition of risk as being the lifetime risk of cancer is now included in the summary.